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Performance Assessment of Cascaded Reservoirs Operation Under the Impact of Climate Change the Case of Lower and upper Dabus Reservoirs, UBN Basin, Ethiopia

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Abstract: Globally the impact of climate change affects many water resources projects, thus it is important to assess its impact on reservoir performance. This study mainly assesses the performance of Upper and Lower Dabus reservoirs under the impact of climate change using Reliability, Resilience and Vulnerability indices (RRV). The future climate variables were projected by General Circulation Model (GCM) and downscaled at the basin level for the A1B emission scenario using the Regional Climate Model (RCM). The trend of streamflow forecasted at outlet (merging to main Abbay River) was assessed and the inflow generated to reservoirs was used to determine reservoirs performance indices (RRV). Finally the inflow to the reservoirs with monthly evapotranspiration from the reservoirs was used as input to HEC-ResSim to simulate and optimize reservoir operation and Power production. The average annual inflow to the upper Dabus reservoirs shows an increasing of 3.17% for early century (2010-2040) and decreasing of 2.08% and 4.46% for mid (2040-2070) and late century (2070-2100) respectively. The average time base reliability of the reservoirs was less than 50% for no reservoir condition and greater than 90% for the other condition considered but volumetric reliability and resilience shows 100% for all conditions. According to the vulnerability result the reservoirs will face shortage of flow which ranges from 8.85% to 88.51%. The result of reservoir simulation shows that the power plant parameters does not shows much significant in all scenarios considered in this study. As a result of these the Dabus sub-basin reservoirs have sufficient potential to produce required power for the country according to reconnaissance level study of the basin demand requirement and even more power can be produced.

Keywords: Upper and Lower Dabus Reservoirs, Climate Change, RCM, RRV-criteria, HEC-ResSim, Reservoir Operation

1. Introduction

Global climate change caused by increasing atmospheric concentration of carbon dioxide and other trace gasses, as well as anthropogenic activities are expected to alter regional hydrological condition and result in a variety of impacts on water resources. Such hydrologic changes will affect nearly every aspect of human wellbeing, from agricultural water productivity and energy production to flood control, municipal and industrial water supply, and fish and wildlife management.

Reasonable allocation of water resources by reservoir operation plays an important role in matching the requirements of sustainable water resources and mitigating the adverse impact of climate variations and changes. All existing global circulation models (GCMs) are projecting a warmer future with increasing greenhouse gases concentrations in the atmosphere [6, 8, 9]. Potential impacts of global warming on hydrology include changes in the hydrologic cycle and the water availability including

reservoir water level [10, 11, 12, 15]. The increase in population growth, economic development and climate change have been proven by IPCC, to cause rise in water demand, necessity of improving flood protection system and drought (water scarcity).

Hence, Assessing the reservoirs performance under climate change is particularly important in improving water management efficiency and benefiting various water use needs such as irrigation on upper Dabus, hydropower generation on both Upper and Lower Dabus projects and also it will be used for recreation, and environmental protection. Besides the mentioned purposes it will be highly used for better management and planning of both reservoirs.

The assessment of the reservoir operation performance will play great role to handle problems of water allocation (reservoir operation) in the basin hence this study endorses well developed planning and managing system dabus reservoirs operation rules.

Generally the objectives of this research are: - To assess the performance of reservoirs operation (Resilience, Vulnerability, Reliability) under the impact of climate change and to develop the reservoirs rule curves for the future scenarios.

2. Description of the Study Area

The Dabus River drains an area of approximately 21030square kilometers. It originates in the high volcanic mountains to the south and flows generally northwards into a large and flat basin known as the Dabus swamp then continuous northward to the Blue Nile River. The River course has a drop of 616 and 638m at upper and lower Dabus dam sites at elevations of 1384 and 1362 m.a.s.l. respectively [2, 13]. The river further drops into an extremely deep narrow canyon prior to leaving the area. The Dabus River has an average annual flow of about 6246Mm^3 even though not yet exploited for hydropower.

A number of potential hydropower sites were identified on the Dabus River, of which the two dam sites namely Upper and Lower Dabus and two weir (left and right alternatives) sites with two power house. These sites are selected for priority development in the Ministry of Water Recourses reconnaissance study in the year (2002). Both projects would involve the creation of a storage reservoir by means of dams to increase the dry season abstractions (and thus the firm power) and to provide the necessary head.

a. Upper Dabus Dam Site: This site is located around $9^040'00''$ N & $34^048'30''$ E coordinate and it is accessible by dry weather road after turning to the left from Benguwa town on the Mendi-Assosa road. It takes about 17km from Benguwa to Metari Birbirsa town and then turning to the right and drive for about 7km, and about 1.5km walking distance.

b. Lower Dabus Dam Site: This site is located around $9^050'06''$ N & $34^052'36''$ E coordinate and it is

accessible by 35.6km from Mendi town. From Mendi about 27km all-weather road on the Mendi–Assosa main road leads to a turning point, to the right. After driving about 8.6km dry weather road and about 1.5 km walking distance the project area will be reached. Generally the location of Upper and lower Dabus dam shown in figure 1.
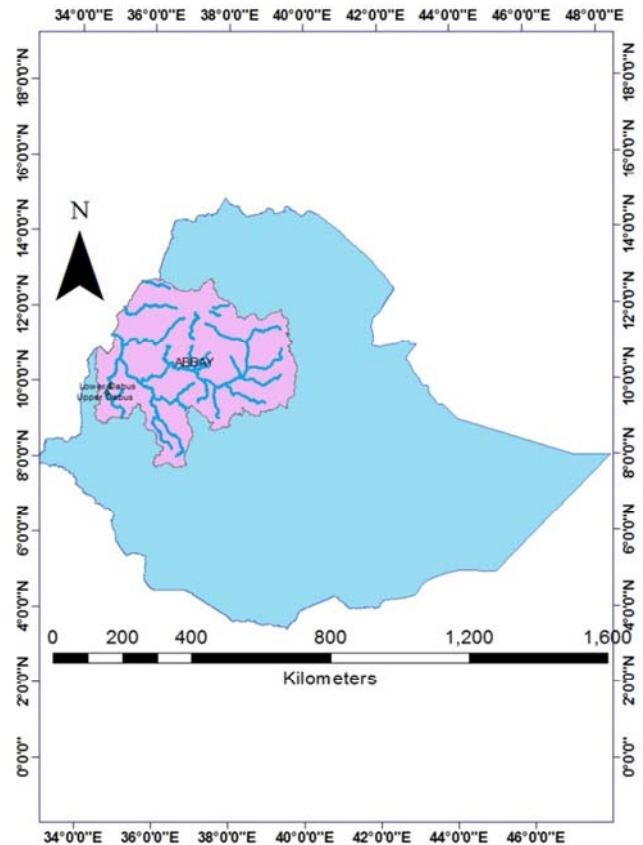

Figure 1. *Location of Upper and Lower Dabus dam.*

Table 1. *Location of proposed Upper and lower Dabus Hydropower Dam.*

Site Name	Longitude East	Latitude North
Dabus I dam (Upper Dabus)	34°48'30"	9°40'00"
Dabus II dam (Lower Dabus)	34°52'36"	9°50'06"

The implementation of these hydropower projects will be expected to minimize the scarcity of the electric power in the country and will also create income at national level that might be used for different infrastructures development.

3. Methodology and Materials

The methodology used in this study includes the following steps (1) Data collection; (2) extraction of climate data series from the climate change scenarios; (3) watershed-based hydrological and reservoir operation modeling; (4) Performance assessment of reservoir water resources under standard operation policy; (5) Preparing Reservoir rule curves.
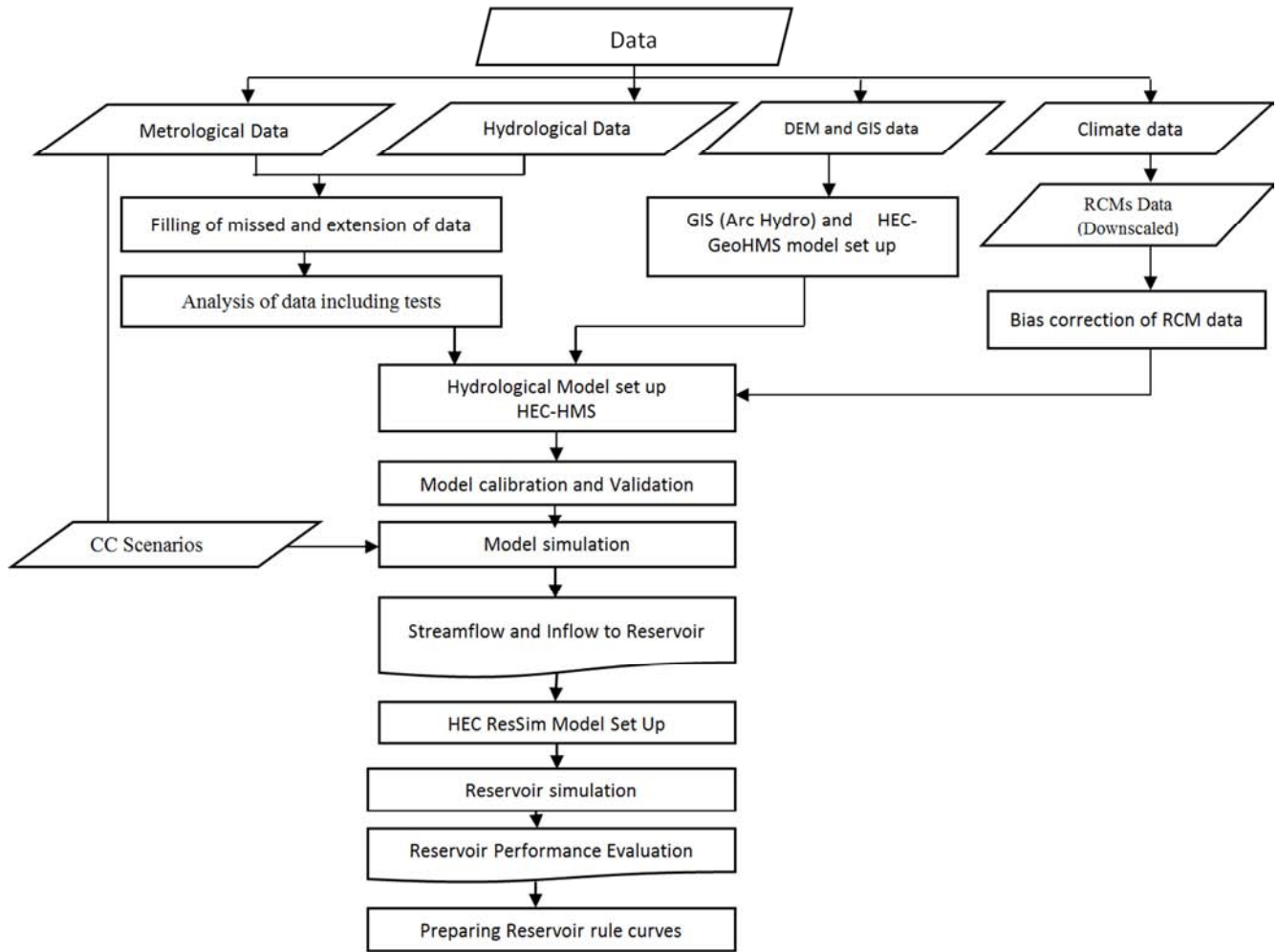
Figure 2. Conceptual framework adopted in the study.

Reservoir System Simulation (HEC-ResSim).

HEC-ResSim is unique among reservoir simulation models because it attempts to reproduce the decision-making process that human reservoir operators must use to set releases. It uses an original rule-based description of the operational goals and constraints that reservoir operators must consider when making release decisions. As HEC-ResSim has developed, advanced features such as outlet prioritization, scripted state variables, and conditional logic have made it possible to model more complex systems and operational requirements [3, 7, 14].

The main input data used for HEC-ResSim are: Reservoir physical characteristics curve (Elevation-Area-storage curve), Evaporation, observed/simulated flow, Key characteristics of reservoir, dam, spillway and turbine and different watershed characteristics obtained from GIS [5]. The main modules that will be used for HEC-ResSim model setup are Watershed Setup, Reservoir Network, and Simulation. Each module has a unique purpose and an associated set of functions accessible through menus, toolbars, and schematic elements. Each module also provides access to specific types of data or results.

Impact Assessment and Performance Indices

A quantitative measure of performance of water resource systems is useful in assessing the operational strategies of the potential future dam projects. The analysis of potential climate change impact on the reservoir system requires simulation of the reservoir water balance under different climate scenarios. An important aspect of planning reservoir systems is to be able to assess their future performance under a wide range of conditions expected during their operating life [5, 16]. Hence, this specific study selects three performance indices (metrics) that are used to evaluate the climate change impact on the two reservoirs comparatively, these are; *reliability* (time-based reliability and volumetric reliability), *resilience* and *vulnerability* indices.

Reliability

Reliability can be defined as the probability that a reservoir will be able to meet, within the simulation period, the target demand in any given interval of time (often a year or a month).

i. Time based Reliability (R_t):

$$R_t = \frac{N_s}{N}, 0 < R_t \leq 1 \qquad (1)$$

Where, R_t - Time based reliability

Ns - The numbers of interval that the target demand is

fully meet.

N - The total number of intervals covering the simulation analysis period.

ii. Volumetric Reliability (R_v)

$$R_v = 1 - \frac{\sum_{i=1}^{N}(D_i - D')}{\sum_{i=1}^{N} D_i} \qquad (2)$$

=1- Total short fall/Total target demand, $0 < Rv \leq 1$

Where: Rv=Volumetric Reliability

D_i=the target demand during the ith.

D'=the volume of water actually supplied or available in the reservoir during the ith period.

N=number of time interval in the simulation period.

Resilience

According to Hashimoto [1] the resilience is the probability of a year of success following a year of failure. Resilience is a measure of defining how quickly a reservoir will recover from a failure.

$$\varphi = \frac{f_s}{f_d}, f_d \neq 0 \qquad (3)$$

Where, φ=Resilience

f_s=is the number of individual continuous sequence of failure periods and

f_d=the total duration of failure

Vulnerability

i. Volumetric Vulnerability: - measures the average volumetric severity of failure during a simulation period and defined by (Hashimoto, 1982) as;

$$\eta' = \frac{\sum_{i=1}^{f_s} Max(S_i)}{f_s} \qquad (4)$$

Where, η'=Vulnerability

S_i=the volumetric shortfall during the ith continuous failure sequence

f_s=the number of continuous sequences of failure

ii. Dimensionless Vulnerability: A more use full expression of vulnerability is its dimensionless form (Thomas et al., 2004) which is expressed as

$$\eta = \frac{\eta'}{D'_f}, 0 < \eta \leq 1 \qquad (5)$$

Where, η'=is in Volumetric units

η=Dimensionless Vulnerability

D_f'=is the constant (average of all demand)

4. Model Setup and Data Analysis

HEC-ResSim Setup and Reservoir Simulation

HEC-ResSim consist three separate sets of functions called modules that provide access to specific types of data within a watershed. These modules are watershed setup, Reservoir Network, and Simulation. Each module has a unique purpose and an associated set of functions accessible through menus, toolbars, and schematic elements [4].

a) Watershed Setup Module

The watershed module is used to create the stream alignment and configure where projects and computation points (stream junctions and control points) are placed.

Creating Watershed Configuration: The Configuration is a specific physical arrangement of the projects and computation points that will be modeled for the study of the watershed. HEC-ResSim provides enough flexibility to create configurations for use both in real-time and planning context. Accordingly, four Dabus Basin configurations – control period configuration (Config_1981-2010), short-term configuration (2011-2040) mid-term forecast configuration (2041-2070), and long-term forecast configuration (2071-2100) have been created in this module.
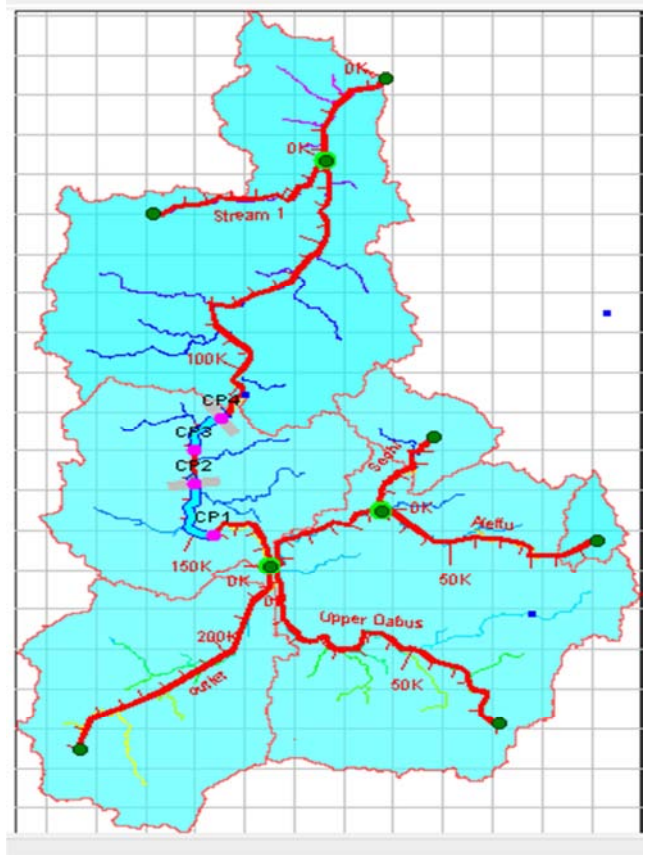

Figure 3. *Dabus Basin watershed setup with Stream alignment and watershed elements.*

b) Reservoir Network Module

This module is used to isolate the development of the reservoir model from the output analysis. In the reservoir network module, we can build river schematic and describe the physical and operational elements of reservoirs model, and develops the alternatives that will be analyzed and used to create simulation.

Developing Reservoir network: A reservoir network represents a collection of watershed elements connected by routing reaches. With the stream alignment in place and the defined watershed configuration, the Upper and Lower Dabus Reservoir that were created in watershed module have

been connected through routing reaches to develop reservoir network for the basin. Diverted outlets that convey water from each project to respective power house and then back to Dabus River have also been added (4).

Defining Physical Properties of reservoirs: Physical components of a reservoir include pool, dam and its outlets, and diverted outlet. HEC-ResSim represents these components as a tree structure. The pool property was defined for each of Upper and Lower Dabus reservoirs using an elevation-storage-area relationship. The dam properties were described through providing their crest elevation and length. Monthly evaporation loss from reservoir is added at the pool component. Outlet properties for controlled and uncontrolled (spillway) have been represented through elevation-capacity (discharge) relationships as provided in the design document. Power generating capacities were described for the power plant sub-component of dam using elevation-capacity relations and through defining installed capacity, efficiency, station use, and hydraulic losses in each case.

Finally tail water elevation or rating curve was also defined under the dam component to fully represent the physical setup of the projects. Figure 5 shows elevation-storage-area relationship for the pool in the case of Upper Dabus reservoir.
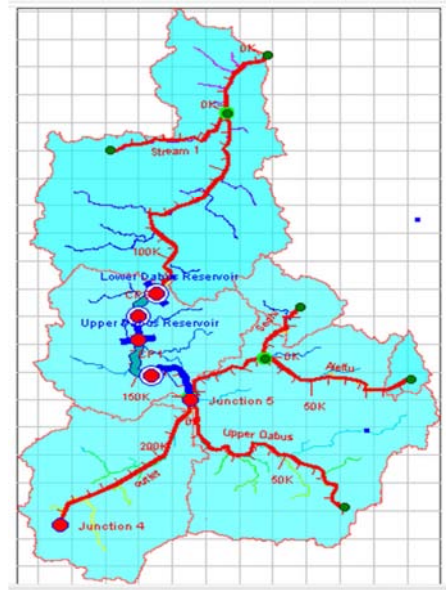

Figure 4. *Dabus Reservoir Network Developed by Reservoir Network module.*
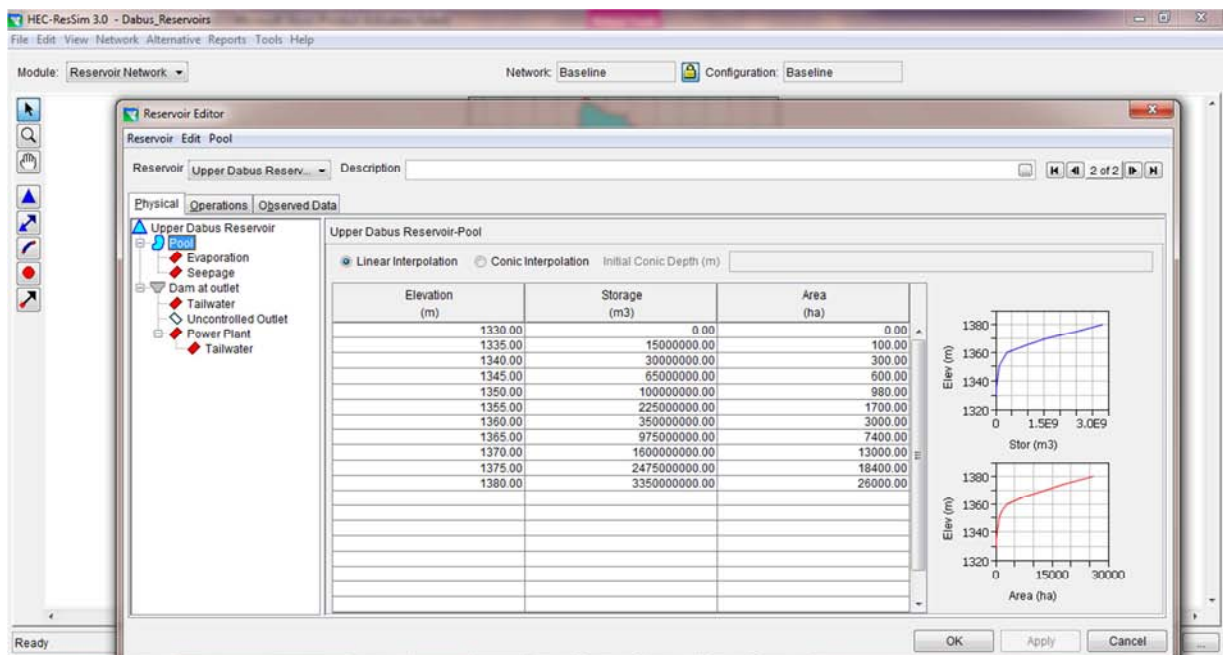

Figure 5. *Elevation-storage-area relationship of Upper Dabus.*

Defining Reservoir Operations Data: The regulation for most reservoirs is described by a seasonally varying target pool elevation commonly called guide curve. Under basic operation, if the pool is below the guide curve, then the objective of the regulator is to reduce releases in order to refill the pool; if the pool is above the guide curve, then the regulator will want to increase releases to draw down the pool.

An operation set consists of three basic features: zones, rules, and guide curves. Zones are operational subdivisions of reservoir pools including flood control, conservation, and inactive pool. Rules represent the goals and constraints upon the releases. The guide curve which is, by default, the top of the conservation zone, represents the target elevation of the reservoir.

Figure 6 shows an operational set of Upper Dabus reservoir.

In this particular study since the reservoirs are on the same river, a tandem reservoir operation rule is applied for reservoir pool and release function rule is applied for both dam outlets and power plants among the different rules available in the program. A Tandem Operation Rule

establishes a tandem system operation where an upstream reservoir (Upper Dabus) operates for a downstream reservoir (Lower Dabus Reservoir) to achieve a storage balance.
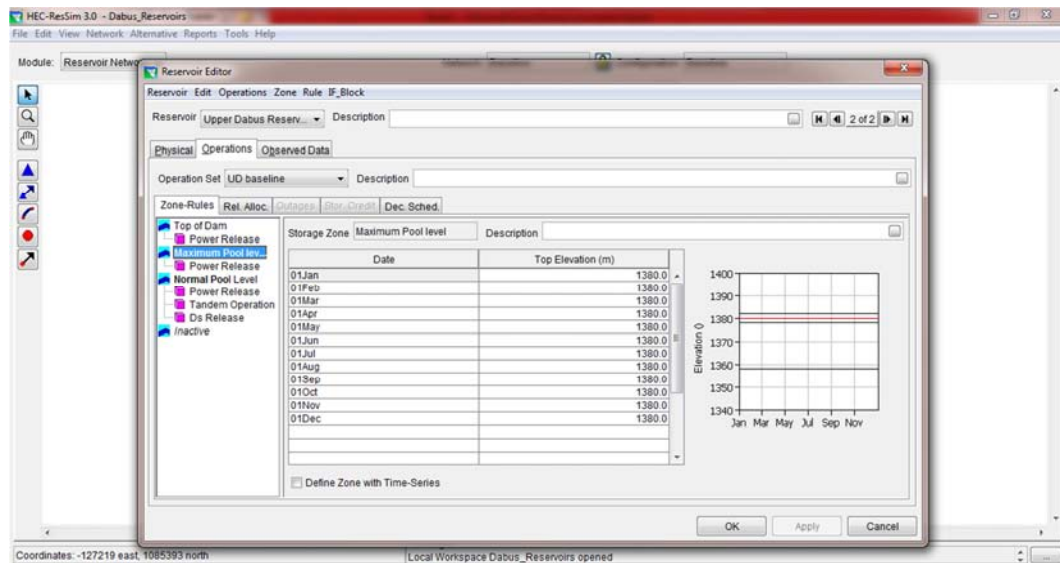

Figure 6. Upper Dabus Reservoir Operational data setup (Maximum Pool Level).

Reservoir systems: These are created by defining system operation rules for two or more reservoirs. ResSim provides for tandem operation to manage the storage distribution for reservoirs on the same stream, and a parallel operation of reservoirs for two or more reservoirs possess common outlet. There are two methods by which the desired storage balance is determined: implicit (default) and explicit (user-defined).

Implicit System Storage Balance Method: The default method in ResSim for determining the desired storage balance in a reservoir system is referred to as the implicit method. This method applies to both tandem and parallel system operations.

Explicit System Storage Balance Method: This method is user defined method in ResSim for determining the desired storage balance in a reservoir system which can be used for an established reservoir system, whether tandem or parallel. In this study four division Inactive, conservation, flood control and top of the dam zones are adopted for both reservoirs to enhance the compatibility of the system.

Defining Alternatives: An alternative consists of a Reservoir Network, an operation set for each reservoir in the network, a storage balance operation set for each reservoir system in the network, a definition of initial (lookback) conditions, and a mapping of all time-series records to identified local inflows.

c) Simulation Module

The simulation module is used to isolate the output analysis from the model development process. Once the reservoir module is complete and the alternatives have been defined, the simulation module is used to configure the simulation.
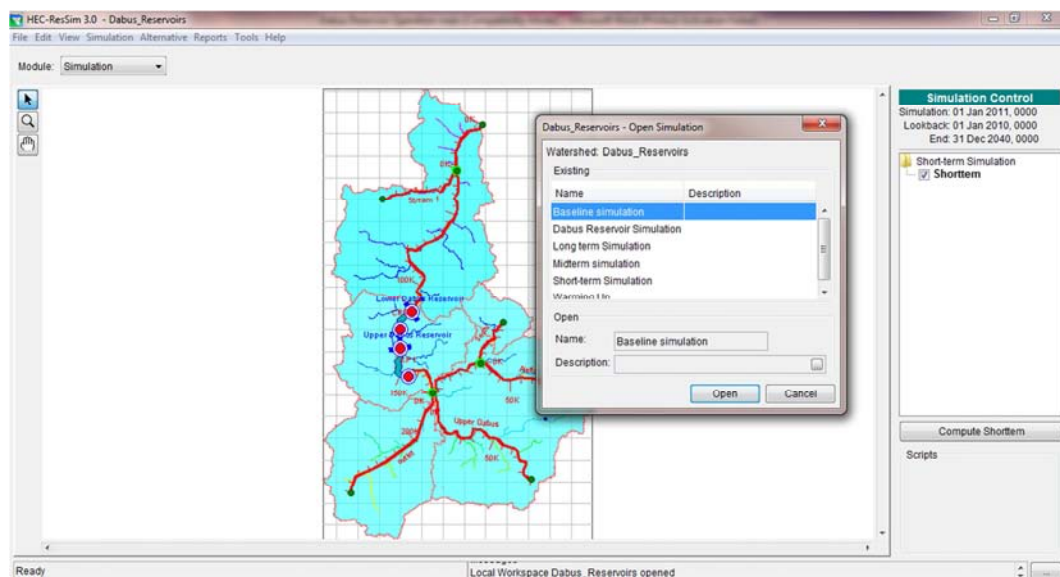

Figure 7. HEC-ResSim Simulation module setup (Baseline Simulation).

5. Results and Discussion

5.1. Generated Inflow to the Reservoirs

The inflow to the Dabus reservoirs is generated by using the bias corrected dynamically downscaled climate variable as an input to the HEC HMS -hydrological model. For comparison purpose the generated inflow is compared with the base period (1981-2010) mean monthly flow. Relative to the base period condition, the simulated future inflow to upper Dabus reservoir shows an average annual decrease in volume by 2.05% and 6.94% in (2041-2070 and 2071-2100) under A1B emission scenario and in (2011-2040) it is expected that the average annual volume of inflow will increase by 1% under A1B emission scenario. The average monthly inflow to the reservoirs exhibits a decreasing trend, for all time horizons in the months of April to June and in the other months little bit it shows both decreasing and an increasing behavior (Figure 8).
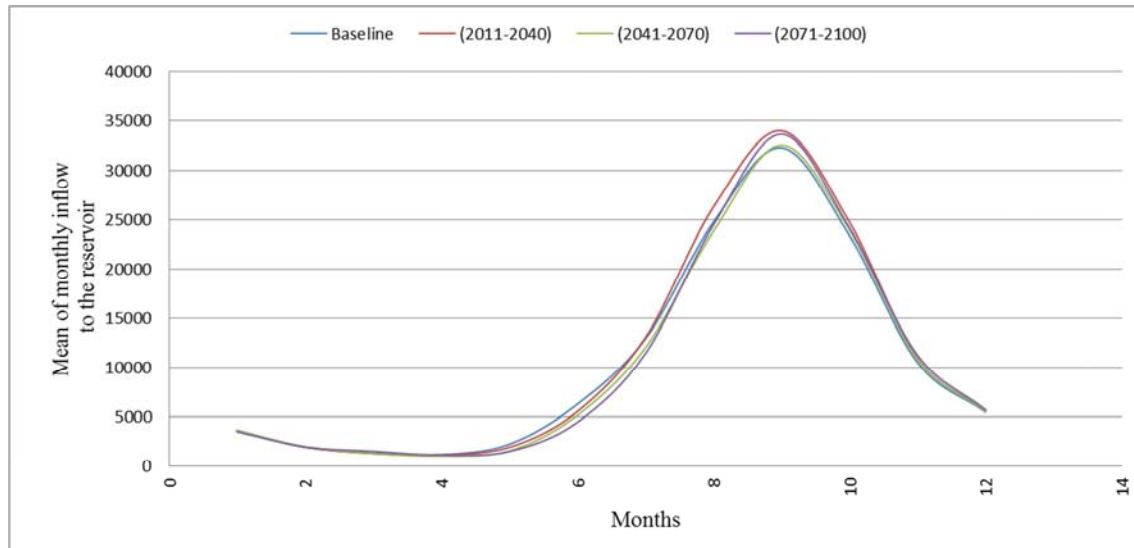

Figure 8. Upper Dabus Reservoir inflow at different time horizons under A1B emission scenario.

5.2. Dabus Reservoirs Performance Indices Evaluation

After generating the reservoir inflow using the HEC-HMS Hydrological model, the Dabus reservoirs were examined by using five performance indices under the standard operation policy of the reservoir operation. Both current and future inflows are considered during quantifying the performance indices. For the sake of comparative purpose the indices also examined without the reservoir existing condition in addition to reservoir empty and full condition.

5.2.1. Reliability of Dabus Reservoirs

Time based reliability (Rt): A value of 100% time based reliability can be explained as, the reservoir can meet the target demand for all its simulation period. The averaged time-based reliability of the Upper Dabus reservoir reveals values of 43.71%, 98.50% and 98.06% for no reservoir condition, reservoir full condition and reservoir empty condition respectively for A1B emission scenarios under all-time horizons and Lower Dabus reservoir reveals values of 47.15%, 98.56% and 46.97% for no reservoir condition, reservoir full condition and reservoir empty condition respectively. Therefore based on the results both upper and lower Dabus reservoir have good ability to meet the target demand for all simulation period.

Volumetric Reliability (R_v): A 100% of volumetric reliability index of reservoir tells that there is no shortage for the reservoir to meet the demanded from the volume (amount) point of view. The result of the analysis for the study area reveals that the annual average volumetric reliability in both reservoirs shows 100% for all conditions and Scenarios. Therefore there is no shortage of water in terms of volume for both reservoirs that indicates the reservoirs have the ability to meet fully the total volume required by targeted demand.

5.2.2. Resilience of Dabus Reservoirs

The Dabus reservoirs resilience which is the indication of how the reservoir system quickly recovers its self from failing to meet the targeted demand to fully satisfy the required demand exhibits a percentage value of 100%, for all conditions and scenarios.

5.2.3. Vulnerability of Dabus Reservoirs

Volumetric Vulnerability (h'): The vulnerability which indicates the average of maximum volumes of shortages in Upper Dabus reservoir reveals that for all future scenarios the shortage is found within the ranges of 146.28m^3-151.77m^3, 1.80Mm^3-1.96Mm^3 and 2.33Mm^3-2.34Mm^3 for no reservoir condition, Reservoir full condition and reservoir empty conditions respectively. Similarly the Lower Dabus reservoir reveals a shortage within the range of 105.153m^3-105.519m^3, 1.004Mm^3-1.356Mm^3 and 2.332Mm^3-2.467Mm^3 for no reservoir condition, reservoir full condition and reservoir empty conditions respectively.

Dimensionless Vulnerability (h): A 100% of dimensionless

vulnerability reflects that the reservoir face a shortage of flow to meet the demand in all simulation period. The average dimensionless vulnerability of the Upper Dabus reservoir is goes up to 63.37%, 7.31% and 11.5% for no reservoir condition, full reservoir condition and reservoir empty condition respectively. Similarly Lower Dabus Reservoir manifests 56.80%, 7.23% and 14.93% for no reservoir condition, full reservoir condition and reservoir empty condition respectively. Generally the evaluated reservoirs performance indices are summarized in table 2.

Table 2. *Dabus Reservoirs performance indices of all current and Future scenarios under different conditions.*

Reservoirs	Conditions	Scenarios	Reservoir Performance Indices				
			R_t (%)	R_v (%)	Resilience (%)	η '	η (%)
Upper Dabus Reservoir	No Reservoir Condition	Baseline (1981-2010)	44.39171	100	100	146.28m³	62.28
		Short term (2011-2040)	44.0084	100	100	147.73 m³	62.90
		Midterm (2041-2070)	43.52469	100	100	149.59 m³	63.69
		Long term (2071-2100)	42.92233	100	100	151.77 m³	64.62
	Reservoir full Condition	Baseline (1981-2010)	98.50324	100	100	0.74Mm³	3.65
		Short term (2011-2040)	98.51237	100	100	1.80 Mm³	8.85
		Midterm (2041-2070)	98.56713	100	100	1.96 Mm³	8.87
		Long term (2071-2100)	98.4211	100	100	1.46 Mm³	7.87
	Reservoir Empty Condition	Baseline (1981-2010)	98.0104	100	100	2.331 Mm³	11.49
		Short term (2011-2040)	98.04691	100	100	2.338 Mm³	11.52
		Midterm (2041-2070)	98.06516	100	100	2.332 Mm³	11.49
		Long term (2071-2100)	98.06516	100	100	2.334 Mm³	11.50
Lower Dabus Reservoir	No Reservoir Condition	Baseline (1981-2010)	47.52213	100	100	100.528 m³	54.81
		Short term (2011-2040)	48.36178	100	100	105.153 m³	57.33
		Midterm (2041-2070)	47.11144	100	100	105.519 m³	57.53
		Long term (2071-2100)	45.59642	100	100	105.515 m³	57.53
	Reservoir full Condition	Baseline (1981-2010)	98.63101	100	100	0.887 Mm³	5.59
		Short term (2011-2040)	98.59451	100	100	1.338Mm³	8.44
		Midterm (2041-2070)	98.56713	100	100	1.352Mm³	8.53
		Long term (2071-2100)	98.46673	100	100	1.004Mm³	6.34
	Reservoir Empty Condition	Baseline (1981-2010)	47.29397	100	100	2.331 Mm³	14.71
		Short term (2011-2040)	48.14274	100	100	2.467 Mm³	15.57
		Midterm (2041-2070)	46.94716	100	100	2.332 Mm³	14.72
		Long term (2071-2100)	45.47778	100	100	2.334 Mm³	14.73

5.3. Dabus Reservoirs Simulation (HEC-ResSim) Results

Dabus Reservoirs operation simulation was done using the daily reservoir inflows which was generated by HEC-HMS model through applying physical properties and operational rules of the reservoirs. Reservoir physical characteristics such as pool level, dam including Release and spillway, and power plant characteristics have been defined in the model. For reservoir operation rule, Tandem operational rule was applied at upper Dabus reservoir to explicitly balance the system storage of Upper and Lower Dabus reservoirs since the reservoirs are connected in series. Additionally power and downstream release rules were applied to control power flow and release for the sustainability of downstream users of the stream.

Dabus Reservoirs Simulation

Upper Dabus reservoir pool level in this scenarios shows a variations which was mostly in the limit of required operational zones of the reservoir. Accordingly figure 9 illustrates that the pool level varies within the required operational zones that is between the minimum operation level (1358m.a.s.l) and the conservation zone top level (1378m.a.s.l).

In short-term, the upper Dabus reservoir simulation result of this scenario shows the reservoir fully meet the required daily power expected to be produced which is about 97.68MW. Actually the power plant has high production capacity which ranges from the required amount to 344.2MW. Accordingly the actual power generated, power generating capacity, Generated Energy and Power flow of upper and Lower Dabus Dam power plant are illustrated in figures 10 and 11 respectively.

In midterm forecast, in the same manner of short-term reservoir simulation, the upper Dabus reservoir simulation result of this scenario also shows the reservoir fully meet the required daily power expected to be produced which is about 97.68MW. The average power production in this scenario is 313.1 MW.

As short-term and mid-term scenarios, the long-term reservoir simulation, the upper Dabus reservoir simulation result of this scenario also shows the reservoir fully meet the required daily power expected to be produced which is about 97.68MW. The average power production in this scenario is 307.6MW.

Generally, Even though the required power production meet, the producing of the plants shows little decrease in power production due to climate change impact.
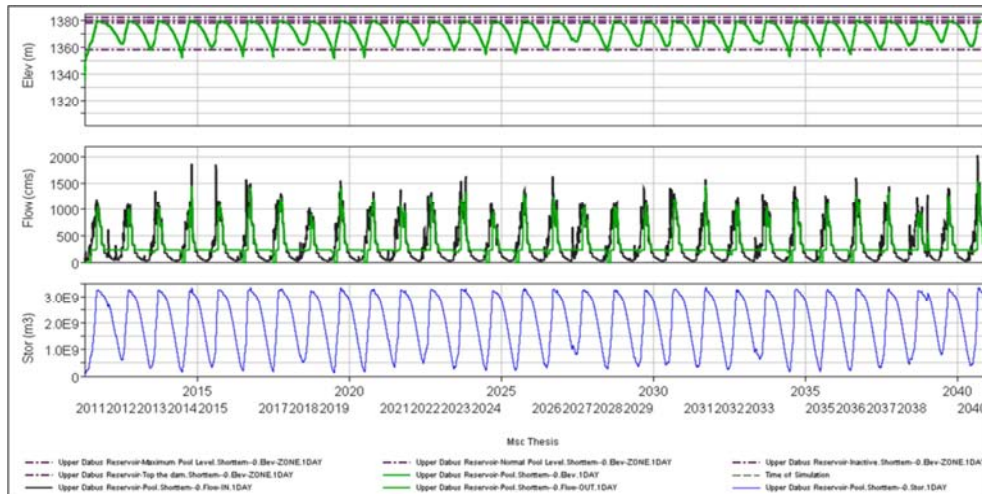
Figure 9. Upper Dabus Reservoir HEC-ResSim Standard Pool level, Storage, Inflow and outflow in short-term forecast scenarios.
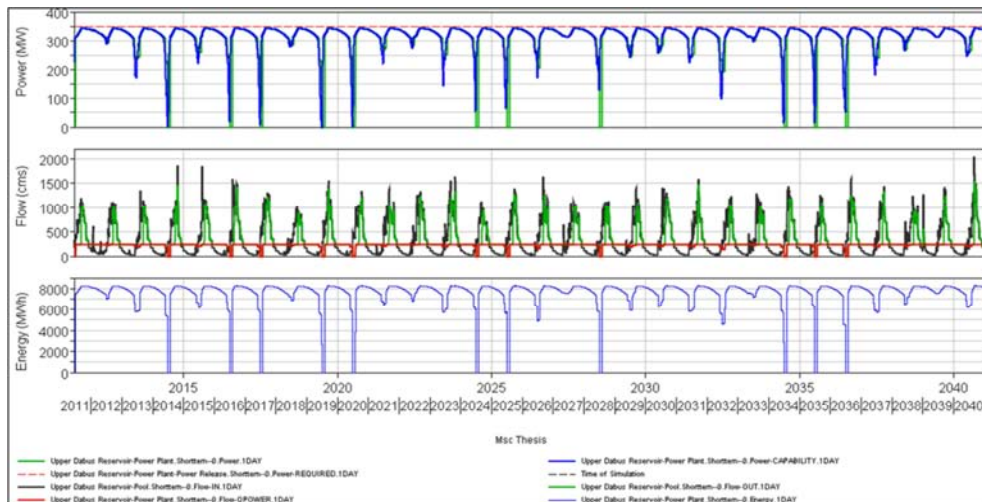

Figure 10. Upper Dabus Dam Power plant HEC-ResSim Standard Power Production, Energy production and Flow for power production plot of short-term forecast scenarios.
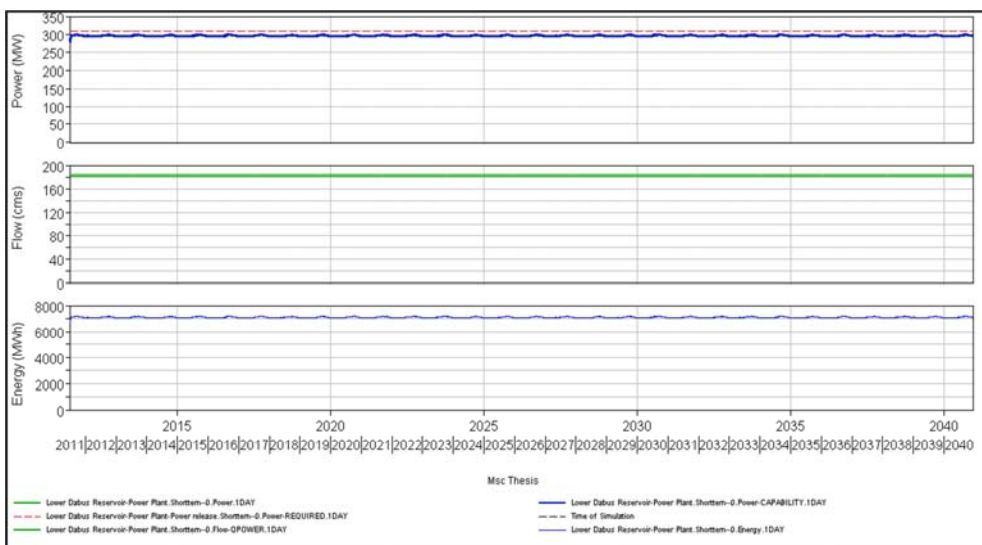

Figure 11. Lower Dabus Dam Power plant HEC-ResSim Standard Power Production, Energy production and Flow for power production plot of short-term forecast scenario.

5.4. Dabus Reservoirs Operational Rule Curves

At the time when this research has conducted only Hydropower project was studied at reconnaissance level. As a result of these no more complex reservoir rule curve was expected to be developed only demand for hydropower production and minimum streamflow for downstream users were considered. Accordingly the reservoir rule curves (guide curves) of Dabus reservoirs were developed for future time horizon of (2011-2040), (2041-2070) and (2071-2100) under the impact of climate change (A1B emission scenarios) to plan/achieve the target objective of the projects. In both Dabus reservoirs and all future time horizons the pool level is within the identified range, that is well above the Lower operation Rule Curve and below the Upper operational Rule Curves in each month as outlined during the reconnaissance level study. Detail illustration of the Upper and Lower Dabus reservoirs monthly Rule Curves are shown in Figures 12 and 13 respectively.
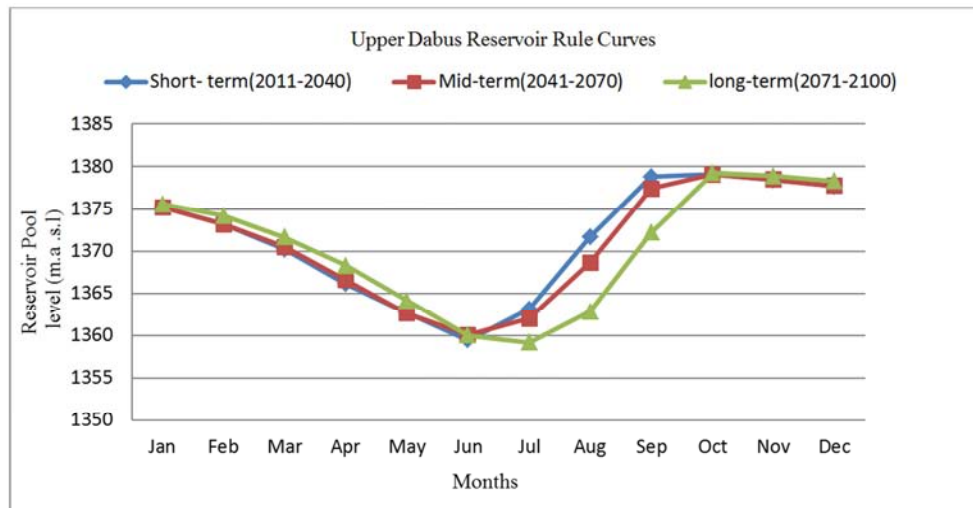

Figure 12. *Upper Dabus Reservoir Rule Curves of Future scenarios*.
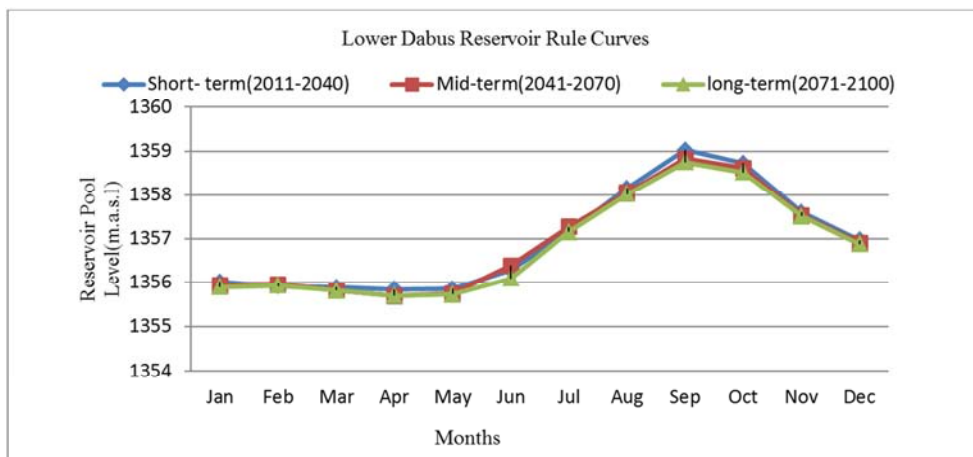

Figure 13. *Lower Dabus Reservoir Rule Curves of Future scenarios.*

6. Conclusions and Recommendations

6.1. Conclusions

Climate is not easy to be exactly forecasted even with the advanced technologies of the 21st century. As a result of these, the study of climate change impact assessment of Dabus Cascade Reservoir operation is highly essential. In this study the Reservoir operation was done by HEC-ResSim and reservoir performance evaluation indices (Reliability, Resilience and Vulnerability) were quantified to assess the Reservoirs performance and climate change impact. Based on this particular study the following are concluded:

1. Dabus reservoirs have high capability to meet the required target demand in the next century if it is wisely managed.
2. The Dabus reservoirs will recover itself from failure to meet the demand that satisfying the target draft within a short period of time.
3. Dabus reservoirs will face a shortage of flow to the reservoir and exposed to unexpected flood that may beyond the capacity of spilling structure.

4. Interruption of power production once per a year/for less significant days.
5. The reservoirs rule Curve developed for all future scenarios do not show great significant differences.

6.2. Recommendations

From the result of this particular study the following main points are highly recommended.

1. In this study the effect of climate change was assessed using the climate variables downscaled dynamically under A1B emission scenarios but using this single emission scenarios may not fully replicate the effect of climate on water resource projects therefore it is better if another emissions scenarios and downscaling methods of finer resolution are adopted and the differences should be assessed.
2. This study should be revised by considering land use, land cover changes, seepage from reservoirs, sediment inflow to the reservoirs, and other water resource developments in the basin in addition to the parameter considered at this time of thesis work.
3. Generally from the result obtained in this study additional water resource projects should be well studied in order to use these sub basin water resources effectively.

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