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The Study on Water Balance in Mlech Reservoir Under Climate Change Effects, Kampot Province

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Abstract

The Mlech Water Treatment Plant (WTP) produce 2,000 m^3/day of drinking water using raw water from Mlech, Kampot Province. Since water demand would be increased in the future, extension of water treatment capacity will be the main challenges within the development plan of Phnom Penh Water Supply Authority (PPWSA). The water balance estimation is also the critical point in order to make a good decision on WTP extension at existing area. Accordingly, the objectives of this study is to analyse water balance in Mlech reservoir by using data from 2002 to 2011, and its prediction in 2030 and 2050. The Rational Method was applied for estimating the streamflow in the reservoir. Water balance was computed following hydrological concept. SWAT and HEC-HMS models were used to predict the future streamflow. The future climatic data 2012-2050 were projected under climate change scenario RCP 4.5 with three general circulation models (GCMs) including IPSL-CM5A-MR, GISS-E2-R-CC, and GFDL-CM3. As a constraint, a baseline reservoir capacity of 11.40 Mm^3/year is maintained. In 2030s, the water quantity will be approximately 58.70 Mm^3/year, 62.09 Mm^3/year and 59.58 Mm^3/year under model IPSL-CM5A-MR, GISS-E2-R-CC and GFDL-CM3, respectively. In addition, the water quantity will be slightly changed in 2050 comparing to 2030. According to the scenario of extension WTP capacity, this study found that the downstream water flow will be decreased to 37.14 Mm^3/year to 33.84 Mm^3/year when WTP's capacity increased from 2,000 m^3/day to 14,000 m^3/day, respectively. Furthermore, the volume of water overflow to downstream for irrigation uses is 30.32 Mm^3/year when WTP's capacity increased to 12,000 m^3/day in 2050. Irrigation water need is about 28.00 Mm^3/year. Finally, we recommend the total WTP's capacity should be extended from 2,000 m^3/day to 10,000m^3/day from Mlech reservoir based on the future water demand.

Keywords: Climate Change, Mlech Reservoir, Rational Method, Streamflow, Water Balance.

1. Introduction

In Kampot province, there has one water treatment plant in Phnom Penh Water Supply Authority (PPWSA) service area that is located in Chum Kiri District. It can produce 2,000 m^3/day of drinking water supply. PPWSA's services area has 6 communes with a population of 43,244 and a growth rate of 0.86% in accordance to the census in 2013. Recently, the total water production in Mlech water treatment plant has produced about 21,539 m^3 from 19th October 2020 to 22nd November 2020. Furthermore, there are five customers (whole seller) already received and connected to the PPWSA water supply at Mlech Water Treatment Plant including Drug Addiction Treatment and Rehabilitation Center (Flow meter DN 40mm), Chhouk Water Supply Company (Flow meter DN 100mm), Armies (Bridgade Division No 11) (Flow meter DN 40mm), and two connections of Heang Tha Company (Flow meter DN 100mm) by 31st December 2020. Recently, the capacity of the existing water treatment plant can produce 2,000 m^3/day of drinking water by extracting raw water from Mlech reservoir. Because of water demand would be increased in the future the extension of water treatment capacity will be the main challenge in corresponding to the development planning. In addition, water resources estimation is also a critical point to make a good decision on extension of water treatment plant at the existing area or looking for a new water source. Climate change is also one of the essential parts of the challenges of sustainable development in developing countries. Climate change represents one of the most significant environmental, social, and economic threats facing the world today (Dhar and Mazumdar, 2009). A changing climate intimately links to changes in the hydrological cycle, and changes in hydrological extremes may be more significant than changes in mean conditions (IPCC 1996a; Katz and Brown, 1992). One of the drivers, such as climate change has become increasingly important topic for water resource management that are affected on future change in stream flow and watershed hydrology. The facing problem with immediate concerns that relate to Land degradation, freshwater shortages, food security, and air and water pollution, which are caused by developing countries. Based on Dhar and Mazumdar (2009) climate change will exacerbate these concerns, leading to further water shortages, land degradation, and desertification. After obtaining the result of water balance, this study could be provided a basic understanding of water balance with the existing water treatment plant of 2,000m^3/day. Moreover, the future extension of water treatment plants will be resilient to the climate change effects on hydrology in Mlech Reservoir. Lastly, water treatment capacity extension and water resources will be found for Water demand in the future in this study. Therefore, this research is conducted to study the water balance by determining average monthly and annually streamflow, predicting the future average monthly, annually streamflow by accessing of climate change scenario and assess the Water Treatment Plant capacity extension by accessing raw water from Mlech Reservoir.

2. Materials and Methods

Study area

The study area is geographically located in Kampot Province, the southwest part of Cambodia. The catchment area is approximately 50.76 km^2 which is delineated by SWAT modeling using Auto-Delineation supported by the ArcMap program. The annual rainfall intensity is around 1,153 mm/year. There are many mountains which were situated surrounding this catchment area. The inlet point to the reservoir or outlet of this catchment was collected water by the main streams from the highest level 624 mASL to the lowest level 50 mASL that which was illustrated in Figure 1. The range of temperature in the catchment area is around 20 ^oC to 35 ^oC. Moreover, the Mlech reservoir area is approximately 1.90 km^2. Therefore, the total study area was around 51.9 km^2.

Data acquisition

All sources and data available were summarized in Table 1. To define catchment area and estimate streamflow, SWAT and HEC-HMS model required data topography (DEM), Land use, soil type, and slope in spatial (raster type). In addition, rainfall is the main parameter for conducting the runoff into the catchment. It is necessary to obtain daily rainfall and evaporation to estimate the water balance in the reservoir. In this study, ten years of observed daily rainfall data were obtained from MOWRAM. Moreover, two years of daily evaporation data were downloaded from the data portal of the Mekong River Commission (MRC) from 2007 to 2008.

Rational methods

The rational method was manually used to determine the streamflow based on rainfall value (Chow et al., 1988). It was estimated streamflow by following Equation 1:

$$Q = 0.278 \times 10^{-6} \times CIA \quad (1)$$

Where Q is a flow (m^3/s), C is the surface runoff coefficient, I is the rainfall intensity (mm/hr), and A is the catchment area (m^2).

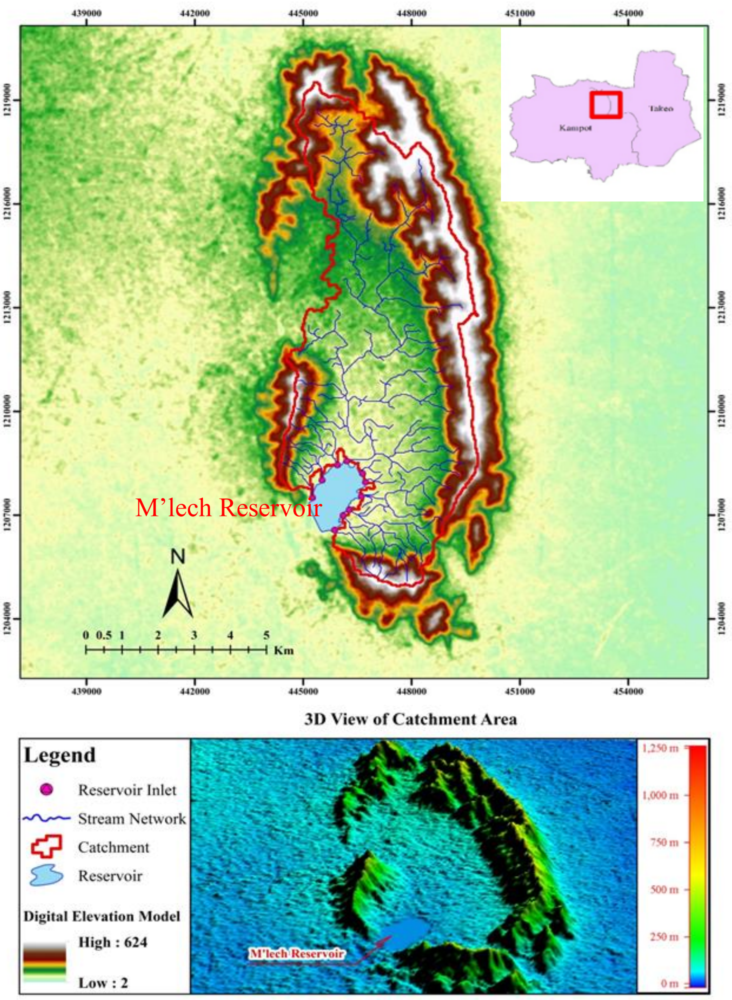


Figure 1.The map of study area 2D and 3D views in Mlech reservoir

Table 1. The data requirement for this study including model requirement and rational method

Data category	**Resolution**	**Period**	**Description**	**Sources**
Topography	30 m	-	Digital Elevation model (DEM)	ASTER-GDEM2
Meteorological data	Daily	2002 to 2011	Rainfall	MOWRAM
Climate Data	Daily	2007 to 2008	Evaporation	Mekong River Commission
Land use	250 m	2002	Raster	Mekong River Commission
Soil Types	250 m	2002	Raster	Mekong River Commission
Meteorological data	Daily	2002 to 2011	Temperature	Global Weather Data
Future Climate data	Monthly	2012 to 2050	Rainfall, Temperature and Evaporation	KNMI Climate Explorer

Hydrological Models

Two models were constructed and simulated streamflow to access climate change such as Soil Water Assessment Tool model (SWAT) and Hydrologic Engineering Center – Hydrological Model System model (HEC-HMS). SWAT model is a hydrological model which potentially delineates catchment area and simulates streamflow. ArcSWAT and ArcGIS extension is a graphical user interface for the SWAT model. The SWAT model was developed and refined by the U.S. Department of Agriculture Research Service (ARS) and scientists at universities and research agencies around the world (Vilaysane et al., 2015). HEC-HMS is the hydrological modeling software developed by the US Army Corps of Engineers Hydrologic Engineering Center (HEC) (Feldman, 2000). The model is designed to simulate the precipitation-runoff processes of watershed systems in a wide range of geographic areas such as large river basins and small urban or natural watersheds. However, in this study, only one model will be selected for future climate change by considering model performance. The performance of the model must be evaluated for the extent of its accuracy.

Model Calibration

These two models were calibrated by different methods. SWAT Calibration Uncertainty Procedure (SWAT-CUP) is an interface that was developed for SWAT since it is a complex model with many parameters that makes manual calibration difficult. Hence, the SWAT-CUP program is an auto-calibration tool that allows for sensitivity analysis, calibration, validation, and uncertainty analysis of the SWAT model (Neitsch et al., 2001). Optimization trials available in the HEC-HMS model have been used for optimizing the initial estimates of the model parameters. The auto-calibration process in the HEC-HMS may not converge to desired optimum results, therefore, the model was calibrated with both manual and auto-calibration. Generally, manual calibration provides the range of the parameters while the auto-calibration process optimized the results (Singh and Jain, 2015).

Model performance evaluation

The model performance in simulating and Rational discharge was evaluated during calibration by inspecting simulated and Rational hydrograph visually and by calculating the Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS), and the ratio of the root mean square error to the standard deviation of measured data (RSR) following Equation 2, 3 and 4. The model performance indicators value is described in Table 2.

The Nash-Sutcliffe efficiency (NSE) determines the relative magnitude of the residual variance compared with the measured data variance (Nash and Sutcliffe, 1970). NSE ranges between -∞ and 1, with NSE = 1 being the desirable value. The range (0 to 1) is generally considered an acceptable level of performance, whereas negative NSE values indicate unacceptable performance

$$NSE = 1 - \left[\frac{\sum_{i=1}^{N} (O_i - P_i)^2}{\sum_{i=1}^{N} (O_i - \overline{O})^2} \right] \quad (2)$$

Percent bias (PBIAS) measures the average tendency of the simulated value to be larger or smaller than their observed counterparts. PBIAS value should be close to zero. Positive values indicate the model underestimation bias and vice versa (Gupta et al., 1999). The formula for PBIAS is:

$$PBIAS = \left[\frac{\sum_{i=1}^{N} (O_i - P_i) \times 100}{\sum_{i=1}^{N} O_i} \right] \quad (3)$$

The ratio of root means squared error to observations standard deviation (RSR) is calculated as the ratio of the RMSE and standard deviation of measured data, as shown in equation (Moriasi et al., 2007).

$$RSR = \frac{RMSE}{STFEV_{obs}} = \left[\frac{\sqrt{\sum_{i=1}^{N} (O_i - P_i)^2}}{\sqrt{\sum_{i=1}^{N} (O_i - \overline{O})^2}} \right] \quad (4)$$

where O_i is the observed value, P_i is the simulated value, $\overline{O}$ is the mean of the observed data,

Table 2. Performance rating of hydrological model, adopted from **Moriasi et al. (2007)**

Performance Rating	NSE	RSR	PBIAS
Unsatisfactory	NSE≤ 0.5	RSR > 0.7	PBIAS ≥ ±25
Satisfactory	0.5< NSE ≤0.65	0.6< RSR ≤0.7	±15 ≥PBIAS <±25
Good	0.65< NSE ≤0.75	0.5 <RSR≤ 0.6	±10≥ PBIAS<± 15
Very Good	0.75< NSE≤ 1	0 <RSR≤ 0.5	PBIAS < ±10

Future climate change scenarios and downscaling

Future Rainfall data is projected from 2009 to 2030 (the 2030s) and 2009 to 2050 (the 2050s) that is retrieved from the KMNI portal data source**.** The period of rainfall data is from 2002 to 2011; however, the average monthly rainfall is corrected and downscaled by using the Bias Correction method by following Equation 5 Minville et al., (2010). Future climate data under scenario RCP 4.5 (Medium emission) by IPCC 5th was corrected with 10 years of observed data in Chum Kiri station. Three general circulation models (GCMs) were employed in this study including IPSL-CM5A-MR (Institute Pierre-Simon Laplace), GISS-E2-R-CC (Goddard Institute for Space Studies), and GFDL-CM3 (Geophysical Fluid Dynamics Laboratory) in corresponding to the MRC report (MRC, 2017).

$$P_{sim,Future} = P_{future} \times \left[\frac{PC_{Obs,Baseline}}{PC_{sim,baseline}} \right] \quad (5)$$

Where $P_{sim,Future}$ is precipitation data in the future already corrected(mm/month), P_{future} is original global precipitation data in the future (mm/month), $PC_{Obs,Baseline}$ is observed precipitation data in specific period (mm/month), and $PC_{sim,baseline}$ is global precipitation data in specific period (mm/month).

Water balance analysis

The total streamflow or runoff from the catchment into the reservoir was determined by rational methods for the baseline period and the best selected hydrological model for future runoff prediction which will be responded to the climate change effects. The future rainfall data period is from 2012 to 2030 and 2012 to 2050. Moreover, the infiltration rate is assumed to be 15% (Kumar et al., 2012) and evaporation from MRC (2007 to 2008) and future evaporation data (2012 to 2030) and (2012 to 2050). Recently, Water has been extracted 2,000m^3/day for water treatment production. In addition, in this study Mlech reservoir is defined as a watershed itself that is received water from rainfall as well. Because the catchment is a mountainous area, there has no discharge from storms or sewerage as urban development. Therefore, the water balance in the catchment is derived by following Equation 7 from the concept of the hydrology cycle.

Water balance in Reservoir = Volume of water into the Lake +Volume of water in M'lech Reservoir received from rainfall- Infiltration volume - Evaporation volume - Existing water treatment plant withdrawal – Water flow into Downstream of Reservoir (7)

3. Results and Discussion

Monthly and annual streamflow by using rainfall data from 2002 to 2011

The average monthly streamflow calculated by the Rational method were presented in Figure 2. Because the area is defined as agriculture and mountainous area, the Coefficient runoff value C is 0.10 which is selected to compute with 50.76 km^2 of the catchment area. As a result, the average streamflow is from 0 to 0.17 m^3/s and from 0.20 to 0.37 m^3/s in the dry and rainy seasons, respectively. In addition, the total annual streamflow is 2.26 m^3/s. The average annual streamflow is 0.18 m^3/s. The maximum monthly streamflow is 0.37 m^3/s in October. Based streamflow is zero in January and February. Therefore, the total of time period that rainfall precipitated on the catchment is approximately 306 days.

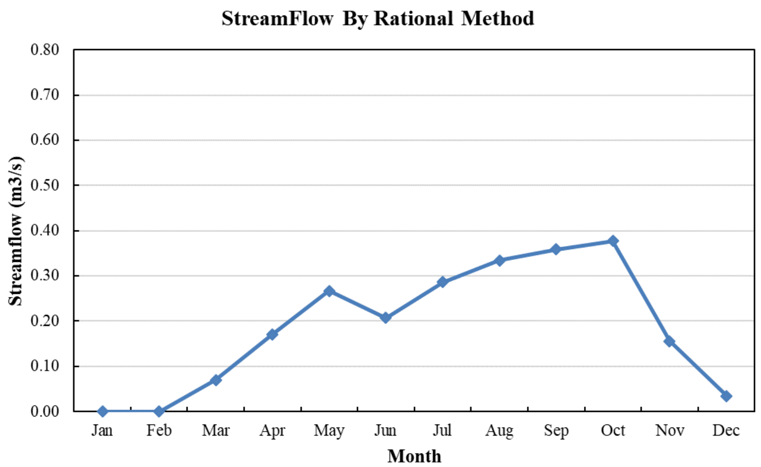


Figure 2. The average monthly streamflow in Mlech Reservoir from 2002 to 2011

Water Balance in Mlech reservoir

Considering the total streamflow is 2.26 m^3/s, the annual net total volume of water in Mlech reservoir obtained from streamflow from the catchment and Mlech reservoir itself is approximately 61.94 Mm^3. Moreover, Mlech reservoir is a continuous flow, therefore, the quantity of water utilization was balanced into five components such as evaporation, infiltration, WTP withdrawal, water flow downstream, and water remaining in Mlech reservoir showed in Figure 3.

As a result, the water remaining in Mlech reservoir is 18% around 11.40 Mm^3 which is closed to the estimated water volume by using the ArcGIS program around 11.46 Mm^3. The water was evaporated 5 % into the atmosphere and infiltrated 15% into the soil. In particular, water will overflow to downstream when the water level is exceeded 6 m of water level and the water gate is fully opened. Therefore, the quantity of water that flowed downstream was about 61% of the total net volume of water.

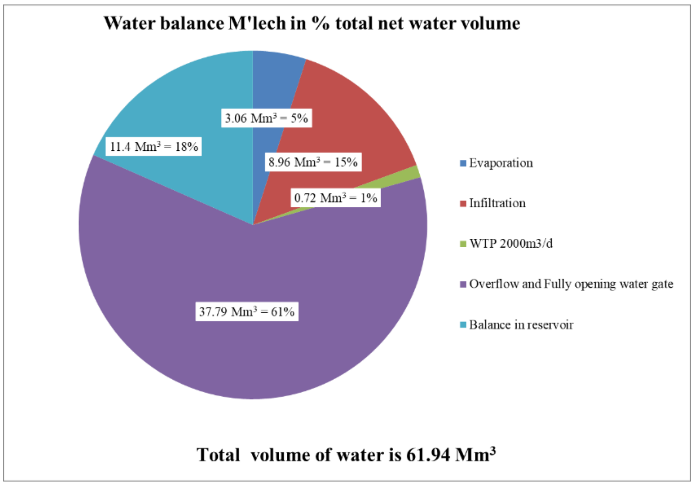


Figure 3. The Water balance in Mlech reservoir using rainfall data in period of 2002 to 2011

Irrigation water need at downstream

Regarding the MOWRAM information, the command area irrigated downstream of Mlech reservoir is approximately 4,000 ha. Moreover, division by season, reported by Farmers living in the site the farmer cultivated 800 ha in the dry season and 1,600 ha in the rainy season. The irrigation crop mostly is paddy rice. According to the FAO, the minimum of paddy rice water need is 450 mm/total growing period and the maximum of rice needs water of 700 mm/total growing period (Table 3).

Table 3. The total demand area of irrigation and paddy rice water demand per period

Description	Unit	Dry season	Rainy season	Total Command area
Irrigation Area	ha	800	1,600	4,000
Minimum Water needed	mm/total growing period	450	450	450
Maximum Water needed	mm/total growing period	700	700	700
Volume minimum	Mm^3	3.6	7.2	18
Volume maximum	Mm^3	5.6	11.2	28

Considering the maximum water demand of paddy rice in the dry season, rainy season, and command area, the irrigation water needs were around 5.60 Mm^3,11.20 Mm^3, and 28.00 Mm^3, respectively (). Among the total remaining water, 11.40 Mm^3 was kept in the Mlech reservoir. According to the result, it confirmed that 2,000 m^3/day of water treatment capacity has no effect on the water balance and irrigation water need in the Mlech reservoir.

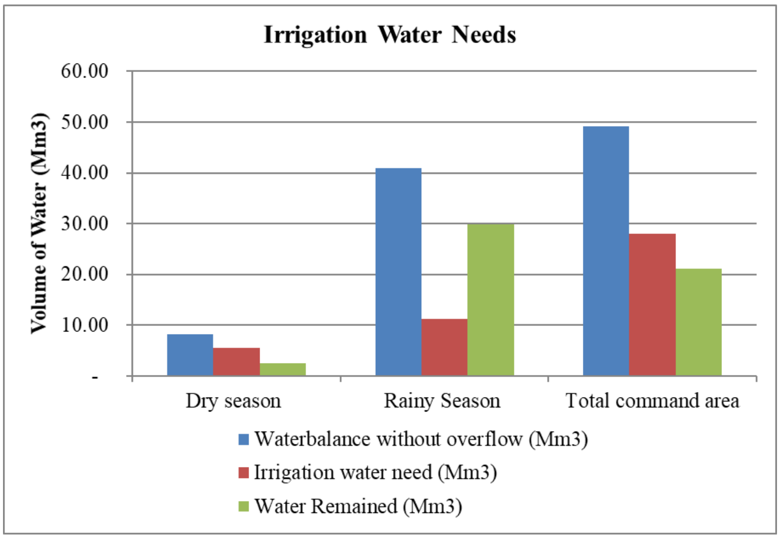


Figure 4. The irrigation water needs in dry season, rainy season and total command area

Model calibration

The streamflow simulated from SWAT was an overestimation so that the models were adjusted sensitive parameters to calibrate the streamflow close to the Rational Method. After adjusting sensitive parameters, the simulated streamflow from SWAT and HEC-HMS models have been compared to the Rational Method as a graphical method shown in Figure 5. The trend of flow graphics is still the same as calibrated results. Regarding the graph, the total streamflow was decreased from 8.93 m^3/s to 6.41 m^3/s by the SWAT model and from 7.85 m^3/s to 7.65 m^3/s by the HEC-HMS model. Hence, the result total flow from the SWAT model was closer than the HEC-HMS model.

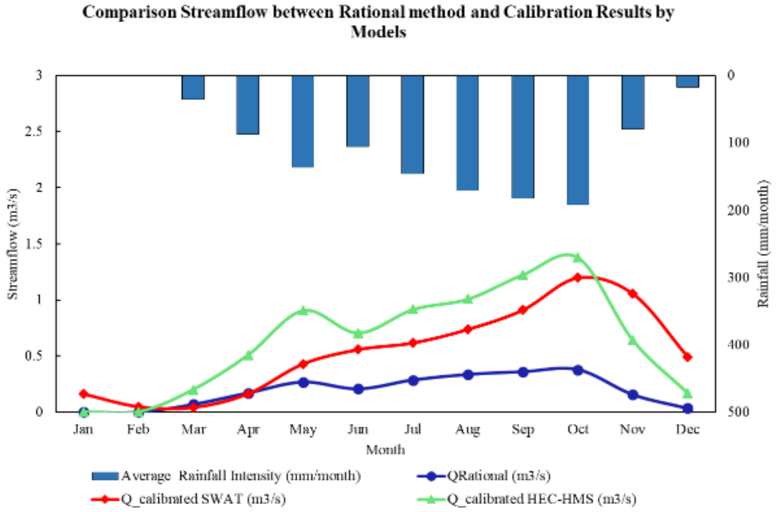


Figure 5. The comparison between streamflow from Rational Method and streamflow obtained from calibrated procedure by SWAT model and HEC-HMS model.

The statistical indicators were selected to indicate the model performance that is determined by daily streamflow from models and Rational methods. The result is compared to model performance indicators illustrated in Table 4. In overall, the results of models were statistically indicated in the unsatisfactory range. The reason is that streamflow from the Rational method can produce the daily streamflow only the rainy day. It created uncertainty daily streamflow even though good monthly streamflow was produced. However, this study is focused on the model which is more closed to the sastisfactory range. Using the SWAT model, the objective functions obtained -0.89 of NSE, 1.38 of RSR, and -194.46 of PBIAS when the satisfactory limitation was higher than 0.5 of NSE, exceeding 0.6 of RSR, and higher ±15 of PBIAS. Using the HEC-HMS model, the indicators obtained -1.61 of NSE, 1.62 of RSR, and -245.24 of PBIAS. Therefore, SWAT model indicators are closed to the satisfactory standard than the HEC-HMS model.

Table 4. The comparison model performance using daily results

Indicator	SWAT Model	HEC-HMS Model	Satisfactory Range
NSE	-0.89	-1.61	0.5< NSE ≤0.65
RSR	1.38	1.62	0.6< RSR ≤0.7
PBIAS	-194.46	-245.24	±15 ≥PBIAS <±25

Therefore, the graphical and statistical indicators confirmed that the SWAT model is the best model to access climate change. Because the calibration results do not fit well with the Rational method, therefore, the ratio between flow by Rational method and flow from calibration was conducted to correct for accessing climate change in the future as shown in Table 5.

Table 5. The ratio correction between streamflow from Rational method and SWAT model

Month	Q_Rational (m^3/s)	Q_Calibrated SWAT (m^3/s)	Ratio
January	1.8×10^{-4}	0.162	0.000
February	0.000	0.048	0.000
March	0.067	0.040	1.687
April	0.170	0.164	1.000
May	0.258	0.429	0.602
June	0.206	0.557	0.370
July	0.276	0.617	0.000
August	0.323	0.738	0.438
September	0.358	0.911	0.393
October	0.364	1.198	0.000
November	0.155	1.056	0.147
December	0.033	0.492	0.067

Effect of climate change in the future by SWAT model

The change of water quantity in future periods

Regarding the changes in streamflow in the future, it will lead the changes of volume inflow in the Mlech reservoir as well. The change in water quantity affected by climate change in the 2030s and 2050s has presented in Figure 6. In the dry season in 2030s and 2050s, the volume will be decreased in three GCM Models except for GISS-E2-R-CC and GFDL-CM3 in 2050s. The change of volume is decreased in the range of 0.3 to 0.29 Mm^3 in the dry season. Water quantity decreased in the future in the dry season due to temperature will be raised. Moreover, in the rainy season the change in water quantity will be decreased except for the GISS-E2-CC model in 2030s. Therefore, the total annual change of water quantity will be declined by 3.27 Mm^3 under IPSL-CM5A-MR model, and 2.34 Mm^3 under GFDL-CM3 model, and it will be increased by 0.11 Mm^3 under the GISS-E2-R-CC model in 2030s. Moreover, the total annual change of water quantity will be decreased by approximately 4.97 Mm^3 under IPSL-CM5A-MR model, 0.30 Mm^3 under GISS-E2-R-CC model and 3.67 Mm^3 under GFDL-CM3 model in 2050s.

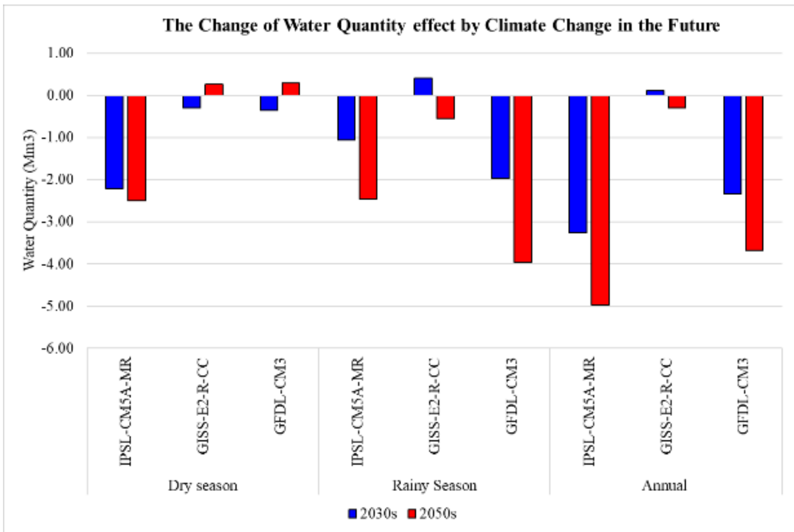


Figure 6. The change of water quantity impact by climate change in the 2030s and 2050s

In response to the Sustainable Development Goal in 2030, the total water balance in Mlech Reservoir was predicted with three different GCMs models represented in Figure 7. Overall, the annual volume of water flow in the Mlech Reservoir is approximately 58.70 Mm^3 under IPSL-CM5A-MR model, 62.09 Mm^3 under GISS-E2-R-CC model, and 59.58 Mm^3 under GFDL-CM3 model in 2030s. In the future, the quantity of water in the reservoir will be evaporated into the atmosphere at around 3.05 Mm^3 under model IPSL-CM5A-MR, 3.09 Mm^3 under model GISS-E2-R-CC and 3.10 Mm^3 under model GFDL-CM3 in 2030s. Since the quantity of water will be decreased, the volume of water overflowing by watergate and overflow also will be decreased. As a result, the quantity of water downstream will be decreased to 35.07 Mm^3 under IPSL-CM5A-MR model, and 35.77 Mm^3 under GFDL-CM model except for GISS-E2-R-CC model will be slightly increased to 37.91 Mm^3/year in 2030s. Therefore, the annual volume of water will remain in Mlech reservoir including 11.39 Mm^3 under IPSL-CM5A-MR model, 11.40 Mm^3 under GISS-E2-R-CC model, and 11.38 Mm^3 under GFDL-CM3 model in 2030s.

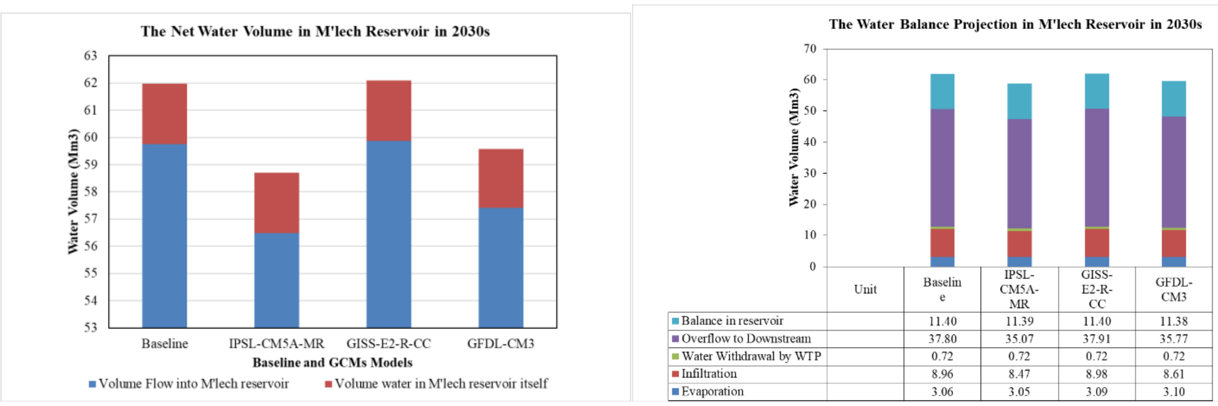


Figure 7. Water balance in 3 difference GCM Models in 2030s in Mlech Reservoir a) Volume of water from inflow and b) the balancing of water in Mlech reservoir

To be easy in terms of results interpretation, the water balance results have been summarized in Figure 8. The result found that the water balance in Mlech Reservoir with future climate models representative will receive water of approximately 56.98 Mm^3 of IPSL-CM5A-MR, 61.69 Mm^3 of GISS-E2-R-CC and 58.20 Mm^3 of GFDL-CM3 in 2050s. The results of water balance in 2050s will be similar to 2030s as in the earlier section. In detail, the quantity of water downstream will be increased to 33.62 Mm^3 of IPSL-CM5A-MR, 37.58 Mm^3 of GISS-E2-R-CC and 34.55 Mm^3 of GFDL-CM3 in 2050s. Therefore, the annual volume of water will keep in Mlech reservoir including 11.39 Mm^3 of IPSL-CM5A-MR model, 11.40 Mm^3 of GISS-E2-R-CC model and 11.38 Mm^3 of GFDL-CM3 model in 2050s.

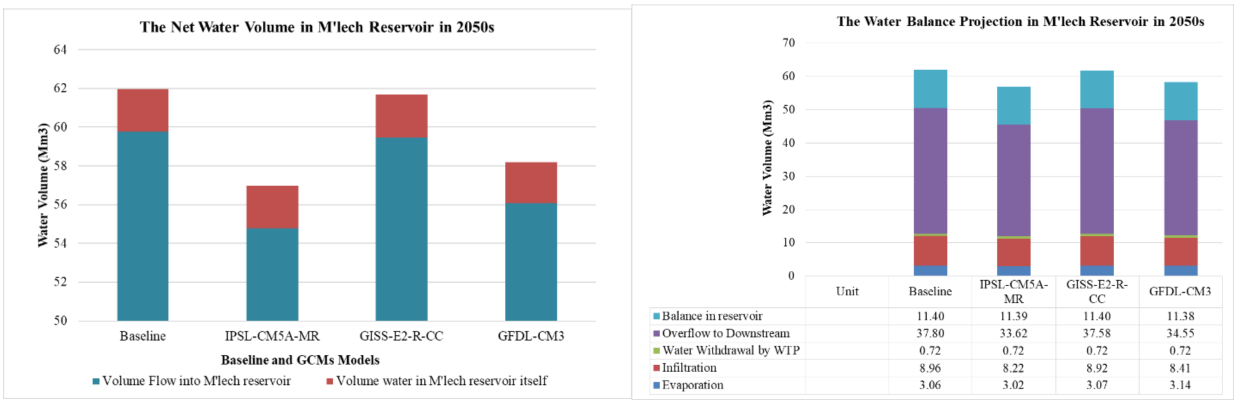


Figure 8.Water balance in three difference GCM Models in 2050s in Mlech Reservoir a) Volume of water from inflow and b) the balancing of water in Mlech reservoir

Access WTP capacity extension in 2030s

To detail the maximum range of total treatment plant capacity extension and responses to the climate change impacts, the IPSL-CM5A-MR model provided the result of the lowest water quantity in the Mlech reservoir compared to other GCM models. Therefore, it was selected to be a baseline for analysis of water balance change in the future. The assessment of change in Water balance in 2030s was presented in Figure 9**.** By graph, when increasing the WTP capacity to around 14,000 m^3/day, the volume of water will probably remain at 31.11 Mm^3 for irrigation downstream.

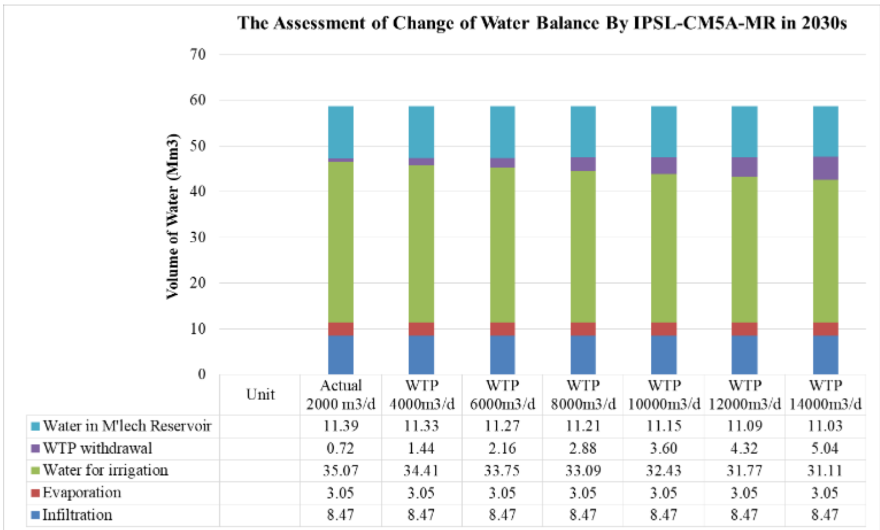
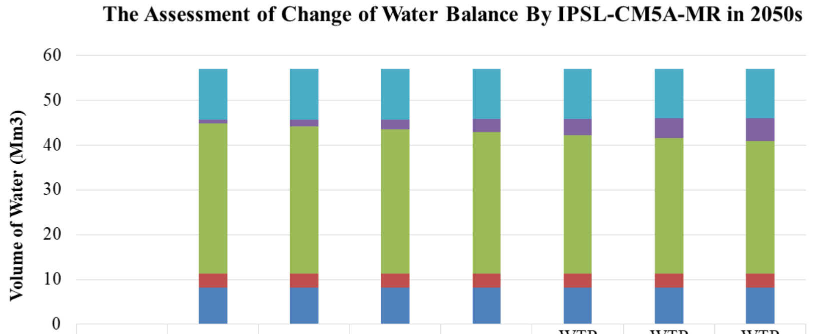


Figure 9. The change of water balance by extension WTP capacity by using balancing following by IPSL-CM5A-MR in 2030s

Access WTP capacity extension in 2050s

Like 2030s, IPSL-CM5A-MR model was selected to be a baseline for analysis of water balance change in the 2050s depending on its lowest predicted water quantity. The assessment of change in Water balance in 2050s was presented in Figure 10. Based on the graph, when increasing the WTP capacity to around 12,000m^3/day, the water will probably remain 30.32 Mm^3 for irrigation at downstream. Unfortunately, when the total WTP capacity increases to 14,000m^3/day, the water will be able to overflow downstream for irrigation remaining around 29.66 Mm^3. This is similar to the maximum water need in 4,000 ha at downstream which is around 28 Mm^3 in the development period of paddy rice. Therefore, the suitable total WTP capacity can extend from 2,000m^3/day to 10,000 m^3/day.



Unit	Actual 2000 m3/d	WTP 4000m3/d	WTP 6000m3/d	WTP 8000m3/d	WTP 10000m3/d	WTP 12000m3/d	WTP 14000m3/d
Water in M'lech Reservoir	11.39	11.33	11.27	11.21	11.15	11.09	11.03
WTP withdrawal	0.72	1.44	2.16	2.88	3.60	4.32	5.04
Water for irrigation	33.62	32.96	32.30	31.64	30.98	30.32	29.66
Evaporation	3.02	3.02	3.02	3.02	3.02	3.02	3.02
Infiltration	8.22	8.22	8.22	8.22	8.22	8.22	8.22

Figure 10. The change of water balance by extension WTP capacity by using balancing following by IPSL-CM5A-MR in 2050s

4. Conclusion

In conclusion, the average annual streamflow in Mlech reservoir is 0.18 m^3/s using the Rational method. In addition, the SWAT model has produced streamflow an acceptable result to access climate change in the future 2030s and 2050s in terms of temperature and precipitation changes. According to the flow from different GCMs models by the SWAT model, the quantity of water will be decreased in the dry season from 0.3 to 0.29 Mm^3. Overall, the total annual change of water quantity will be declined by 3.27 Mm^3 under IPSL-CM5A-MR model, and 2.34 Mm^3 under GFDL-CM3 model, and it will be increased by 0.11 Mm^3 under GISS-E2-RCC model in 2030s. Moreover, the total annual change of water quantity will be decreased by approximately 4.97 Mm^3 under IPSL-CM5A-MR model, 0.30 Mm^3 under GISS-E2-R-CC model, and 3.67 Mm^3 under GFDL-CM3 model in 2050s. In 2030s, the total annual streamflow under RCP4.5 will be approximately 2.13 m^3/s under IPSL-CM5A-MR model, 2.26 m^3/s under GISS-E2-R-CC model, and 2.17 m^3/s under GFDL-CM3 model. Overall, the volume of water flow in the Mlech Reservoir will be approximately 58.70 Mm^3 under IPSL-CM5A-MR model, 62.09 Mm^3 under GISS-E2-R-CC model, and 59.58 Mm^3 under GFDL-CM3 model in 2030s. In addition, the annual volume of water will remain in Mlech reservoir such as 11.39 Mm^3 under IPSL-CM5A-MR model, 11.40 Mm^3 under GISS-E2-R-CC model, and 11.38 Mm^3 under GFDL-CM3 model in 2030s. In 2050s, the total annual streamflow under RCP4.5 will be approximately 2.07 m^3/s under IPSL-CM5A-MR model, 2.24 m^3/s under GISS-E2-R-CC model, and 2.12 m^3/s under GFDL-CM3 model. Overall, the volume of water flow in the Mlech Reservoir are approximately 56.98 Mm^3 under IPSL-CM5A-MR model, 61.69 Mm^3 under GISS-E2-R-CC model, and 58.20 Mm^3 under GFDL-CM3 model in 2050s. Furthermore, the annual volume of water will be kept in the Mlech reservoir such as 11.39 Mm^3 of IPSL-CM5A-MR model, 11.40 Mm^3 of GISS-E2-R-CC model, and 11.38 Mm^3 of GFDL-CM3 model in 2050s. In 2030s and 2050s, the assessment of increasing the water treatment capacity following the IPSL-CM5A-MR model from 2,000 m^3/day to 14,000 m^3/day, the result showed that the water remained in the reservoir will be declined from 11.39 Mm^3 to 11.03 Mm^3 in 2030s and 11.39 Mm^3 to 11.03 Mm^3 in 2050s. Unfortunately, the quantity of water overflowing downstream dramatically decreased from 35.07 Mm^3 to 31.11 Mm^3 in 2030s and from 33.62 Mm^3 to 29.66 Mm^3 in 2050s. However, the volume of water for irrigation is 30.32 Mm^3 when WTP capacity increased to 12,000 m^3/day. This value is still okay for irrigated water need for 4,000 ha around 28 Mm^3 per total crop development period.

5. Recommendation

Regarding the results above, this part provides the recommendation on water resources, technical aspects, and policy such as the following:

1 According to the assessment of scenario extension of WTP capacity around 12,000m^3/day including existing WTP 2,000m^3/day, the water balance in Mlech Reservoir indicated that quantity of water is sustainable and balanced for water uses upstream and downstream.

Therefore, the extension of WTP and production can use raw water at Mlech reservoir for more around 10,000 m^3/day.

2 Regarding the possible quantity of water resource extension, 12,000 m^3/day of total water treatment capacity can supply drinking water for approximately 87,000 habitats or around 17,000 households daily water demand is 110 Liter per capita. This demand has not considered on projection demand for biz environment, industrial and commercial.

3 In addition, responding to the sustainable development goal in 2030s, the population in the PPWSA's service area will be approximately 50,020 people, therefore, the WTP capacity of 12,000 m^3/day can provide enough drinking water for the future population.

4 The population in 2050 will expect to be 59,365 habitats, the 12,000 m^3/day of total capacity WTP still be acceptable for supplying water to this population forecasting.

5 The detailed study focusing on future water demand should be conducted for selecting the WTP capacity extension in the range of 2,000 m^3/day to 10,000 m^3/day.

6 Furthermore, the limitation of this study has no infiltration data, which consequently leads to uncertain outcomes of water balance. Therefore, there is the technical suggestion to improve water balance results by determining with observed infiltration data nearby the catchment.

7 Moreover, to obtain the water balance and water quality in this study, the catchment area should be maintained and protected the land use in the catchment area.

8 Lastly, if the study area has daily observed streamflow, the models should conduct again to fit parameters to get a good calibration result.

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7. Declaration

The authors declare that there is no conflict of interest regarding the publication of this paper.

8. References

Chow, VT, Maidment DR, and Mays LW. 1988. Applied Hydrology. McGraw-Hill Book Company. New York.

Dhar S, and Mazumdar A. 2009. Impacts of climate change under the threat of global Warming for an agricultural watershed of the Kangsabati River. *International Journal of Civil and Environmental Engineering*, 1 (3), 154-163.

FAO.https://www.fao.org/3/s2022e/s2022e07.htm

Feldman AD. 2000. Hydrologic modeling system HEC-HMS: technical reference manual: US Army Corps of Engineers, Hydrologic Engineering Center

Gupta HV, Sorooshiann S, Yapo PO. 1999. Status of automatic calibration for hydrologic models: Comparison with multilevel expert calibration. *Journal of hydrologic Engineering*, 4(2), 135-142.

IPCC. 1996a. Climate change 1995: the science of climate change. In: Houghton, John T,Meiro Filho, LG, Callander, Bruce A, Harris, Neil, Kattenburg, Arie, Maskell, Kathy. Climatic change, 584.

Katz RW, and Brown BG. 1992. Extreme events in a changing climate: variability is more important than averages. *Climatic change*, 21(3), 289-302.

Kumar G, Singh SK, Murari K, Pandey V, Om Prakash, Sinha BK, and Prasad SK. 2012. Quality Assessment and Recharge Potential of Ground Water of Chasnala Coal Mines, A Case Study. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 3(1), 959-968

Minville M, Krau S, Brissette F, and Leconte R. 2010. Behaviour and performance of a water resource system in Québec (Canada) under adapted operating policies in a climate change context. *Water Resources Management*, 24(7), 1333-1352.

Moriasi DN, Arnold JG, Van Liew MW, Bingner RL, Harmel RD, Veith TL. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the Asabe*, 50(3), 885-900.

MRC. 2017 Summary of the basin-wide assessments of climate change impacts on water and water related resources in the Lower Mekong Basin.

Nash JE, and Sutcliffe JV. 1970. River flow forecasting through through conceptual models' part I-A discussion of principles. *Journal of Hydrological*, 10(3), 282-290.

Neitsch S, Arnold J, Kiniry J, and Williams J. 2001. Soil and Water Assessment Tool-Version 2000-User's Manual, 2001.

Singh WR, Jain MK. 2015. Continuous Hydrologic Modeling using Soil Moisture Accounting Algorithm in Vamsadhara River Basin, India. *Journal of Water Resource and Hydrologic Engineering*, 4(4), 398-408.

Vilaysane B, Takara K, Luo P, Akkharath I, Duan W. 2015. Hydrological streamflow modelling for calibration and uncertainty analysis using SWAT model in the Sedone river basin, Lao PDR. Procedia Environmental Sciences, 28, 380-390.