Assessment of climate change impact on future streamflow at Bernam river basin Malaysia

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Abstract. Climate change is anticipated to bring variability in future streamflows in various watersheds. Soil Water Assessment Tool (SWAT 2012 version) was evaluated using streamflow data (1976–2006), and assessed the potential impacts of climate change driven by projections from ten global climate models (GCMs) under three Representative Concentration Pathways (RCPs) scenarios (RCPs 4.5, 6.0 and 8.5) on future streamflow (2010-2039), (2040-2069) and (2070-2099) at the Bernam River Basin, Malaysia. The model efficiency during calibration and validation, with coefficient of determination ($R^2$), Nash-sutcliffe efficiency (NS), Percent Bias (PBIAS) and Root mean square error-standard deviation ratio (RSR) is 0.67, 0.62, -5.4 and 0.64; and 0.64, 0.61, -4.2 and 0.65, respectively. This shows that SWAT coupled with GIS extension is a good tool for continuous simulation. Future streamflow is projected to decrease in all future periods during main and off-seasons. However, the changes would be more pronounced during the off-season period with a significant decrease of -9.14 % under the worst-case scenario (RCP8.5). Therefore, the Basin may likely to experience tremendous pressure in the late century due to low streamflow, particularly during the off-season months.

1. Introduction
Climate change has a serious impact on water resources, affecting the availability of water; disrupting the environment and food security. Water availability and its consistent quantification in individual river basins and also on a global scale have been a global issue [1]. As a result, irrigation performance in agro-hydrological watersheds has been impaired. The water use by irrigation has been estimated to reach about 2,500 km³ year⁻¹ globally [2]. The sector has the highest total water withdrawals in Malaysia [3]. However, the streamflow is anticipated to be less due to the climate change forcing [1, 4-6]. The water supply to the irrigation scheme is being sourced from the Bernam River Basin, which is among the
largest in Malaysia. The hydrological processes of this river basin are paramount to the planning and management of the irrigation scheme's potential water requirements. Water shortage is an annual issue for the scheme. Therefore, adaptation strategies under the climate change forcing are essential for global water and food security.

Hydrologic models are reliable tools for evaluating the hydrological impacts of changes in the environment [7]. The development of remote sensing (RS) techniques and the Geographic Information System (GIS) was a driving force for improving hydrological modeling processes. Such systems have enabled and promoted the broader use of watershed models worldwide [8]. SWAT is a semi-distributed model developed for simulating impact of land management practices on water and sediment in watershed [9]. Among the major advantages of SWAT over other hydrological models is ability to incorporate with ArcGIS interface to delineate the catchment area. In addition, it simulates and forecasts streamflows under current and future climate scenarios. This was one of the reasons why the model was chosen for this study. The model has been widely applied in the world on various river basins, to simulate flood events, climate change impact assessments and river restoration [10-16]. The model was applied recently in Malaysia as reported in the works of [5] and [17].

2. Methodological approach

2.1. Study area

Bernam River Basin is an agro-hydrological watershed with area of about 1097 km² situated in Malaysia (Figure 1). The area has two distinct seasons dry-season and wet-season [18]. The rainfall of the area is averagely 2,000 mm annually, and its distribution is mostly between the months of October and January. However, the distribution of rainfall is unpredictable between the months of January–August and consequently, crops rely mostly on irrigation during that period for yield sustenance [19, 20]. The basin is the major water source for the Integrated Agricultural Development Area (IADA) Northwest Selangor Rice Irrigation Scheme.

![Figure 1. Delineated Upper Bernam River Basin (UBRB), Malaysia.](image-url)
2.2. Hydrologic modeling system for Bernam river basin
SWAT model was applied for simulating streamflow of Bernam River Basin. The model requires data such as digital elevation model (DEM), soil-map and landuse-map of the region under consideration (Figure 2). Others include rainfall, temperature, relative humidity, wind-speed and solar-radiation. The spatial data was processed with Arc-Hydro tool and ESRI’s ArcGIS Program. Daily archives of the climate data from 1976-2006 were obtained from the Department of Irrigation and Drainage (DID) Malaysia.

2.3. Model calibration and validation
After successfully running the model, it was calibrated and validated. A developed SWAT Calibration and Uncertainty Procedures (SWAT-CUP) software [21] was used to perform sensitivity analysis, model evaluation. Monthly discharge data from 1981 to 1998 was used for the model calibration from 1999 to 2006 was used for validation.

2.4. Simulation of future impacts of climate change
To represent the impact of climate change on the watershed area, a statistical method “Delta change factor” method [22] was applied to reduce the bias between the global climate models (GCMs) outputs and observations for high-resolution in future climate projections at station scale. A period from 1976 to 2005 was considered as the baseline for this study. In addition, for the future periods three time sperm were considered as (i) 2020s (from 2010 to 2039), (ii) 2050s (from 2040 to 2069) and (iii) 2080s (from 2070 to 2099) driven by projections from ten different GCM using three emission RCP 4.5, RC P6.0 and RCP 8.5 scenarios.

3. Results and discussion
3.1. SWAT calibration and validation
The model performance during the evaluation was satisfactory as shown in figure 3. Four criteria were statistically employed to evaluate the hydrological goodness of fit; coefficient of determination ($R^2$), Nash Efficiency (NS), Percentage Bias (PBIAS) and ratio of Root-mean square error-standard deviation (RSR). Results of $R^2$, NS, PBIAS and RSR for the calibration period are 0.67, 0.62, -5.4 and validation periods were 0.64; and 0.64, 0.61, -4.2 and 0.65.
3.2. Future changes in streamflow at Bernam basin outlet

The validated SWAT model was used for determining potential flow changes at the basin outlet. Temperature and rainfall are the key climatic variables that bring about the change in climate of an area. The mean temperature was predicted to increase under RCPs 4.5, 6.0 and 8.5 by an average of 1.2 °C, 1.2 °C and 2.01 °C, respectively compared to the baseline period. In the other hand, rainfall may slightly increase in the wet-season (July to December) and reduce in the dry-season (January to June) during the future period. The wet-season average changes are projected to be 1.0, 0.8 and 2.4%. Whereas, the average changes for the dry season were respectively -2.4, -3.2 and -3.7% under RCP 4.5, RCP 6.0 and RCP 8.5 scenarios.

Projected streamflow decreases in all three projected periods during main and off-seasons as shown in figures 4. However, the changes is more pronounced during the off-season period with a significant decrease of -9.14% under the RCP8.5 in 2050s.
4. Conclusion

SWAT model was evaluated for the assessment of climate change impacts in Bernam watershed, Malaysia. Findings from the model evaluation indicate acceptable temporal and spatial flow forecasts. The $R^2$, NS, PBIAS and RSR is 0.67, 0.62, -5.4 and 0.64 during calibration; and 0.64, 0.61, -4.2 and 0.65 during the validation period.

Climate change impacts were assessed by combining all simulations for the three projected periods irrespective of the GCM using the validated SWAT model. Compared with baseline streamflow records, predicted future streamflow would tend to decrease in all projected periods during main and off-seasons. However, the changes would be more pronounced during the off-season period with a significant decrease under the worst-case scenario (RCP8.5). It could be deduced from the results that the basin may likely to experience tremendous pressure in the late century due to low streamflow, particularly during the off-season months. Therefore, integrated water resources management strategies are necessary to ensure adequate irrigation activates for rice production in the Basin. The information will help decision-makers prepare and control future water needs of the irrigation scheme.

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