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Modelling Capabilities of Two Physically Based Hydrologic Models for Streamflow Simulations

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Abstract—**Hydrologic processes in a watershed are typically simulated through hydrologic models due to their availability in the public domain and improved computational capacities. However, choosing a suitable model among the many available for a region of interest is challenging. In our work, we compared streamflow generated by the Soil and Water Assessment Tool (SWAT) and the Hydrological Engineering Centre-Hydrologic Modeling System (HEC-HMS) in the Kalu River Basin (KRB), Sri Lanka, frequently impacted by floods. Meteorological data including rainfall and temperature from 1990 to 2000 were used to force the hydrologic models. In addition, we used soil, land use data and a digital elevation model (DEM) for model development. During the calibration phase (1993-1996) of the SWAT model we achieved a coefficient of determination (R^2) of 0.93 and a Nash-Sutcliffe Efficiency (NSE) of 0.87. In the validation phase (1997–2000), these indices yielded values of 0.87 and 0.66, respectively. In the HEC-HMS model, during the calibration phase, R^2 and NSE yielded values of 0.89 and 0.91 while in the validation phase, these indices yielded values of 0.77 and 0.56, respectively. The exceedance probabilities at 10%, 50%, and 90% derived from flow duration curves (FDCs) from HEC-HMS and SWAT models were 395, 159, 54.5 and 400.5, 148, 29.11 (all in m^3/s), respectively. Similarly, for observed flow, these values were 344.40, 138.98, and 65.35 m^3/s, respectively. Thus, the FDCs suggest that the HEC-HMS model captures low flows reasonably. Neither model accurately resembled high flows. During the first inter-monsoon season (March-April) the HEC-HMS and SWAT underpredicted 3%, and 4% while during the northeast monsoon season (December-February) the models underpredicted 9%, and 2%, respectively. Similarly, during the second inter-monsoon season (October-November) and the southwest monsoon season (May-September), HEC-HMS and SWAT models overestimated observed flow by 11%, 5%, and 8%, 17%, respectively. Both models performed reasonably well on a seasonal basis with slight over-predictions and under-predictions. Overall, it is clear that both models can generally capture the hydrology of the KRB.**

Keywords—**Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS), Soil & Water Assessment Tool (SWAT), Kalu River Basin (KRB), streamflow**

I. INTRODUCTION

In light of the need to understand watershed processes, hydrologic models play a central role. Hydrological models can be categorized according to how they represent and capture real-world phenomena. Lumped models treat catchments as homogeneous units, thus ignoring the spatial variability. In contrast, semi-distributed and fully distributed models incorporate spatial variability of land use, soil, climate, etc. Fully distributed models offer even more detailed spatial representation. Depending on the mechanism of simulating hydrologic processes, models can be further classified as process-based models: which use physical principles to simulate the mechanisms of the entire hydrological cycle, physics-based models: which use physical laws to focus on specific components or processes within the hydrological cycle, and empirical-based models: which rely on relationships between inputs and outputs [1].

Owing to advancements in computation power and programming, the capacity to represent complexities in hydrologic processes has steadily increased over the recent decades [2]. Several widely used hydrologic models are the Soil and Water Assessment Tool (SWAT) [3], the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) [4], the J2000 model [5], the GR4J model [6], the Hydrologic Simulation Program FORTRAN (HSPF) model [7], the MIKE-SHE model [8], and the Modular Finite-Difference Ground-Water Flow (MODFLOW) [9].

However, hydrologic models have shown varied performance across different scales and hydro-climatic regions [10]. Many countries with limited data require modeling strategies better to understand the quantity and quality of water resources. SWAT and HEC-HMS showed varied performance when applied to the same river basin. For instance, Khoi [11] found that the SWAT model adequately captured the high flow events compared to low flows. SWAT outperformed HEC-HMS in the Srepok River, Cambodia. Shekar & Vinay [12] found that HEC-HMS provided better agreements in low flow simulations than SWAT. However, when considering the overall performance, the SWAT model outperformed HEC-HMS in the Hemavathi catchment in India. Ismail *et al.* [13] compared both models and found that

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the HEC-HMS model underestimated high flows in the Bernam River Basin in Malaysia. Prakash *et al.* [14] revealed that the HEC-HMS outperformed SWAT on the daily scale in the Kabini basin, India. Otieno et al. [15] demonstrated that both models could be successfully calibrated for diverse climatic conditions. However, their performance varied significantly depending on the specific hydrological characteristics of the basin in a study carried out for the Tana catchment in Kenya. These studies highlighted the strengths of SWAT and HEC-HMS models, suggesting that a combination of both models can potentially provide a broader understanding of hydrology.

In our study the SWAT and HEC-HMS models were chosen for continuous streamflow simulations in the Kalu River because of their performance elsewhere in Sri Lanka by De Silva *et al.* [16], Nandalal & Rathnayake [17], Gunathilake *et al.* [18], Herath and Wijesekera [19], Sirisena *et al.* [20], Shelton [21]. De Silva et al. [16] showed that the HEC-HMS model is capable of simulating events and continuous flows in the Kelani River Basin, Sri Lanka. Nandalal & Rathnayake [17] used the HEC-HMS model in the KRB to evaluate the streamflow under selected precipitation events. Gunathilake, *et al.* [18] demonstrated that the HEC-HMS model was capable of event-based modeling in a tropical catchment called "Seethawaka River Basin". Herath and Wijesekera [19] revealed that the HEC-HMS model serves as an important tool for managing water resources in the Maha Oya Basin in Sri Lanka. Sirisena et al. [20] used the SWAT model to project river flow and sediment transport under anticipated climate change scenarios in the KRB. Shelton [21] found that the SWAT model accurately replicates river flow for specific catchments within the Mahaweli River Basin, Sri Lanka. Moreover, the availability of both models in the public domain also made them preferable choices for our work. According to the authors' best understanding, this study is the first of its kind which performs an inter-comparison between two hydrologic models in a Sri Lankan watershed.

II. MATERIALS AND METHODS

A. *Study Area*

The Kalu River basin (KRB), covering an area of 2598 km^2, is the second largest in Sri Lanka based on discharge volume encompassing a catchment area of 2816 km^2 [22]. It is also one of the river basins most prone to flooding in the country. The river originates from the country's central hills in the wet zone at an altitude of 2250 m above mean sea level (MSL) and runs through the western slopes until meeting the Indian Ocean in Kalutara (refer to Fig. 1). The Kalu River discharges 4000 million m^3 of water into the sea [23, 24]. Further, the basin receives a yearly precipitation ranging from 1878 to 4476 mm, although there were occasional variations. For instance, the annual variation in 2014 was between 2000 and 6000 mm [25].

As shown in Fig. 2 (a), the land use in the KRB is diverse, comprising barren land (1%), built-up areas (12%), cultivation (14%), forest cover (21%), grassland (2%), vegetation (49%), and water bodies (1%). Orthic Acrisols (Ao), a dark brown loamy soil, and Humic Acrisols (Ah), a subsoil rich in clay, are the two main soil types that predominate the basin (Fig. 2 (b)). Cambie Plinthic Acrisols (Ap), a clay-rich subsoil, Chromic Luvisols (Lc), greyish brown to dark brown clayey soil, and Arenosols (Qc), a sandy-textured soil are the other types of soil types found in the KRB [25, 26].

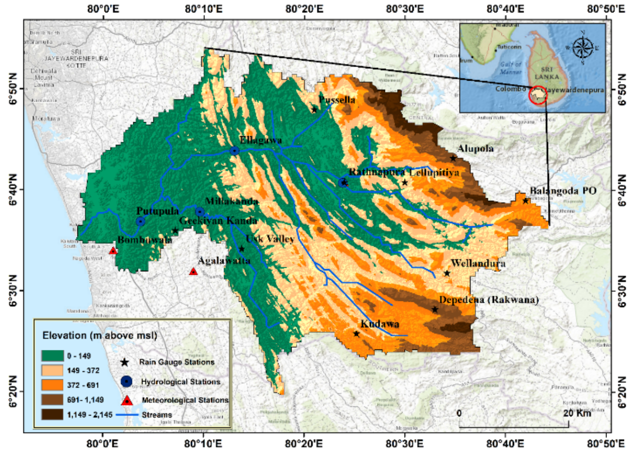


Fig. 1 Study area.

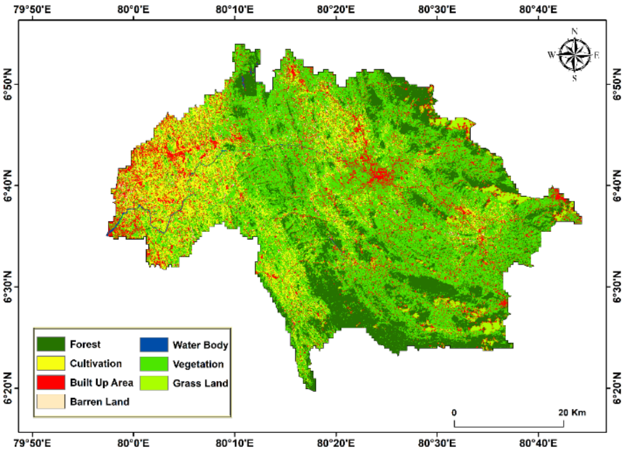


Fig. 2 (a) Land use of the Kalu River Basin.

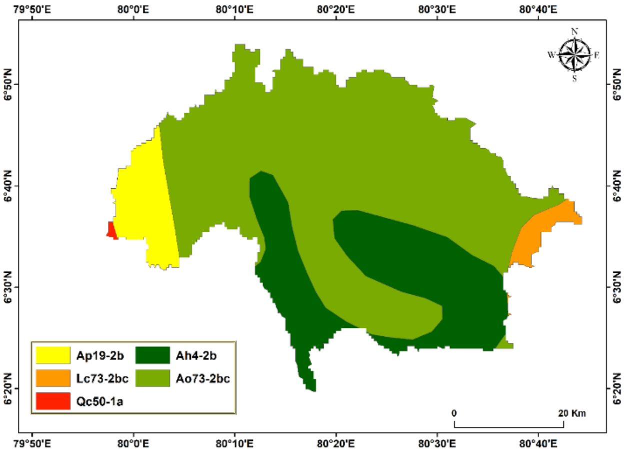


Fig. 2 (b) Soil types in the Kalu River Basin.

B. *Data*

The description of date used in this study is given through Table 1. The data comprises meteorological, hydrological, and soil information, land use maps, and a digital elevation model (DEM). Daily rainfall records from 1990 to 2000 were obtained from the Department of Meteorology Sri Lanka. Further, daily temperature records were acquired from three meteorological stations. Daily river flow data from 1990 to

2000 was collected from the Department of Irrigation, Sri Lanka.

Table 1. Temporal and spatial data used

Data Type	Temporal Resolution	Spatial Resolution	Period	Source
		Temporal data		
Temperature	Daily	Point data	1990-2000	DM
Rainfall	Daily	Point data	1990-2000	DM
Streamflow	Daily	Point data	1990-2000	DI
		Spatial data		
DEM		30 m×30 m		USGS HydroSHEDS
Soil cover		450 m×450 m		FAO DSMW
Land use		30 m×30 m		USGS

DM - Department of Meteorology, Sri Lanka; DI - Department of Irrigation, Sri Lanka;
USGS - United States Geological Survey; FAO DSMW - Food and Agriculture Organization Digital Soil Map of the World

C. Hydrologic Models

1) SWAT Model

The SWAT, eco-hydrological model was developed by the United States Department of Agriculture's (USDA) Agricultural Research Services Division [27]. The accessibility of the SWAT tool in the public domain, along with its robust algorithms for simulating hydrologic processes, sediments, and nutrient simulation mechanisms. Noteworthy, the user-friendly Geographic Information Systems (GIS) interface has contributed to the models' extensive global use. This semi-distributed, physically based model operates on a daily scale. Homogeneous units of topography, land use, and soil, are aggregated into a spatial unit referred to as the hydrological response unit (HRU) which represents the finest level of simulation in SWAT [28]. The water balance equation is the governing equation of the SWAT model [29].

$$SW_t = SW_0 + \sqrt{(R_{day} - Q_{surf} - ET_a - W_{seep}} - Q_{gw} \quad (1)$$

where SW_t = final soil water content (mm), SW_0 = initial soil water content (mm), t = time (days), R_{day} = amount of precipitation (mm), Q_{surf} = amount of surface runoff (mm), ET_a = amount of evapotranspiration (mm), W_{seep} = amount of water entering the vadose zone from the soil profile (mm), and Q_{gw} = amount of return flow (mm) [30].

2) HEC-HMS Model

The HEC-HMS model was developed by the United States Army Corps of Engineers [4]. The HEC-1 which was the earliest version of the HEC-HMS underwent upgrades to incorporate new features alongside advancements in computer technology and numerical modeling techniques [31]. The latest version of HEC-HMS can be used for studying reservoir outflow capacity, flood frequency analysis, urban floods, and the effects of urbanization [32]. It is global user base has grown because of the availability in the public domain. HEC-HMS has demonstrated its usefulness both in event and continuous scale analyses across diverse regions around the globe [33–35]. The HEC-HMS model consists of elements including a basin model, meteorological model, control specifications, and time series configuration [36].

D. Methodology

1) Watershed model development

SWAT and HEC-HMS models were developed for the KRB and were simulated on a continuous time scale adopting a methodology similar to Makumbura *et al.* [37], Babel *et al.* [38], and Shelton [21]. We adopted a similar methodology for calibration and validation for both models. Further, manual calibration was performed by adjusting the parameters within allowable ranges. The calibration was carried out by first adjusting the watershed's long-term water balance which was then followed by monthly calibration.

The optimal values were determined through statistical metrics. The initial three years of the simulation period (from 1990 to 1992) were taken as a warm-up period to equilibrate different water storages in the hydrological cycle. Thereafter, the streamflow data from 1993 to 1996 were used for calibration, and data from 1997 to 2000 were used for validation. Sirisena *et al.* [20] documented that, inaccuracies exist in the rating curves at the Patupaula streamflow gauging station after 2000. Therefore, for this study, we used streamflow data from 1990 and 2000 for model calibration and validation purposes.

2) SWAT model development

SWAT 2012 [39] version was utilized in this study. The basin was delineated into seven subbasins. The outlets for sub-basins were defined according to the location of streamflow gauging stations and the basin outlet. A total of 105 hydrological response units (HRUs) were created. The soil conservation service–curve number (SCS-CN) method was used to simulate surface runoff while the Muskingum method was used for river flow routing which are model default options [30]. The curve number (CN) was adjusted within 5% of the model's default value. The default values of the SOL_AWC factor, which affects soil moisture capacity, were modified by varying within ranges of ± 0.04. To consider the influence of capillary action, the ESCO factor, the parameter that regulates depth distribution to satisfy the soil evaporative requirements, varied between 0.7 and 0.95.

3) HEC-HMS model development

HEC-HMS 4.10 [40] version was employed in this study. The basin was divided into seven subbasins. The outlets for sub-basins were established according to the location of streamflow gauging stations and the basin outlet. SWAT model delineation was carried out by adopting the same procedure as for the HEC-HMS model. The baseflow recession method, the Muskingum and lag methods, the Clark Unit Hydrograph, and the Soil Moisture Accounting model (SMA) were utilized to estimate baseflow and perform streamflow routing, direct runoff, and precipitation losses. Precipitation for subbasins was determined using gauge weights calculated through the Thiessen polygon method. According to recommendations made by De Silva, *et al.* [17], Herath and Wijesekera [20], and Nandalal and Ratnayake [18], initial parameter figures were determined from observed daily discharge data.

E. Modeling Precipitation Losses

Precipitation losses were modeled using the SMA method. The parameters of SMA infiltration were estimated by considering guidelines given by Chow *et al.* [41] and De Silva *et al.* [16]. Since SMA supports hydrologic simulations under wet and dry weather situations, it has been recommended for continuous-scale model simulations [4] and was used by Chea and Oeurng [42], Ouedraogo *et al.* [43].

F. Modeling Direct Runoff

The Clark Unit Hydrograph method was chosen to model direct runoff because it necessitates fewer parameters compared to other available methods. For the Clark Unit Hydrograph, the time of concentration and storage coefficient are required [44]. The time of concentration was calculated by following the guidelines of De Silva *et al.* [17].

G. Modeling Baseflow

Baseflow in the KRB was modeled using the baseflow recession approach. The initial base flow at the start of the simulation must be defined [16]. To achieve a strong correlation between the simulated and observed streamflow data, multiple trials were performed to adjust the initial discharge, recession constant, and ratio to peak based on the values used in the literature.

H. Modeling Channel Routing

Channel routing was carried out through two methods. The Muskingum method was employed for reaches that are closer to the coast while the lag method was applied to model the channel flow in the steep terrains following Nandalal and Ratnayake [17]. Lag time was estimated to be 0.70 percent of the time of concentration [45]. The Muskingum method requires two parameters which are "k" measured in hours and "x" which has no units.

I. Model Performance Evaluation

The statistical effectiveness of the model was evaluated using indicators including normalized objective function (NOF) [46], Nash-Sutcliffe Efficiency (NSE) [47], percentage bias (PBIAS) [48, 49], and the Coefficient of Determination (R^2) [50]. Values of 0, 1,0%, and 1, respectively of the above indices indicate an ideal match between the simulated and observed streamflow values. The Eqs. (2) and (3) were used to calculate the performance measures, NOF [46] and NSE [47].

$$NOF = \frac{1}{\bar{O}}\sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - O_i)^2} \quad (2)$$

$$NSE = 1 - \frac{\sum_{i=1}^{n}(S_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \quad (3)$$

The PBIAS, a metric frequently used to evaluate the effectiveness of watershed modeling, [48, 49], was calculated using Eq. (4).

$$PBIAS = \frac{\sum_{i=1}^{n}(S_i - O_i)}{\sum_{i-1}^{n} Oi} \times 100\% \quad (4)$$

R^2 was computed using Eq. (5), which compares the variability of observed and predicted values together differs from the variability of observed values alone [50].

$$R^2 = \frac{n\sum O_i.S_i - \sum O_i.S_i}{(\sqrt{n(\sum {O_i}^2) - (\sum O_i)^2}) \times (\sqrt{n(\sum {S_i}^2) - (\sum S_i)^2})} \times 100\% \quad (5)$$

where O_i = observed discharge, S_i = simulated discharge, n = number of observed or simulated data points, and $\bar{O}$ = mean of the observed discharge.

The recommended ranges of the above skill matrices corresponding to various performance ratings are given in Table 2.

Table 2 Recommended ranges of skill matrices [51]

Performance rating	NOF	NSE	PBIAS	R^2
Very Good	0	0.75-1	≤±10%	0.8-1
Good	-	0.65-0.75	±10 to ±15	0.6-0.8
Satisfactory	-	0.5-0.65	±15 to ±25	0.6-0.4
Unsatisfactory	1	<0.5	≥±25	<0.4

J. Flow Duration Curves

Both models relied on the same rainfall dataset spanning from 1993 to 2000. The SWAT model distributes rainfall to subbasins based on the distance of the basin centroid to the rainfall station. In contrast, the HEC-HMS model distributed rainfall among subbasins using Thiessen Polygons.

The flow duration curves (FDCs) were developed and compared for SWAT; HEC-HMS simulated flows against observed flows. The high flows (10% exceedance), medium flows (50% exceedance), and low flows (90% exceedance) were analyzed from the generated FDCs. Sri Lanka experiences four rainfall seasons: the first inter-monsoon season occurring in March and April, the southwest monsoon season from May to September, the second inter-monsoon season from October and November, and the northeast monsoon season lasting from December to February.

III. RESULT AND DISCUSSION

A. SWAT Model

The calibrated parameters and their fitted values are given in Table 3.

Table 3. Fitted values of parameters used for calibration of the SWAT model

Parameter		Description		Default Value	Fitted Value
GW_DELAY		Groundwater delay		31	2
ALPHA_BF		Base-flow alpha factor		0.048	0.99
ESCO		Soil evaporation compensation factor		0.95	0.7
GW_REVAP		Groundwater "revap" coefficient		0.02	0.2
SOL_AWC		Available water capacity of soil	AO73	0.156	0.196
			AP19	0.175	0.175
			AH4	0.108	0.148
			LC73	0.156	0.196
CN2		Curve Number	AGRL (Agricultural land-Generic)	83	79
			FRST (Mixed Forest)	73	69
			RNGE (Grasslands/Herbaceous)	79	79
			URML (Urban Medium Density)	72	68

Model calibration and validation produced 'very good' [51] results at the Patupaula station, located along the main river. The analysis of the predicted and measured monthly runoff at Patupaula Station during the calibration period (1993-1996) and the validation period (1997-2000) is illustrated in Figs. 3(a) and 3(b). Generally, low flows at Patupaula were underestimated.

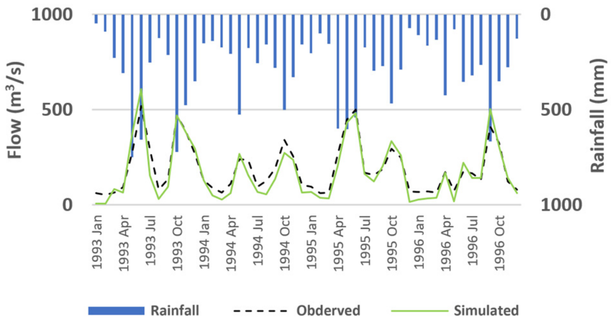


Fig. 3(a) Monthly hydrograph during calibration (1993-1996) at Patupaula station for the SWAT model.

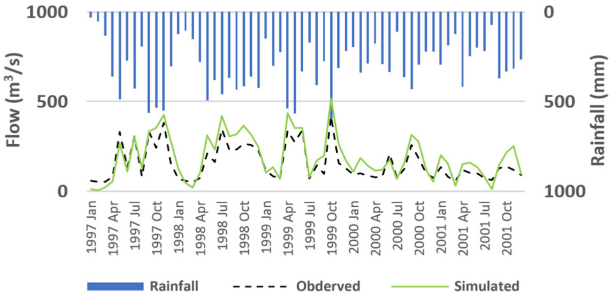


Fig. 3(b) Monthly hydrograph during validation (1997-2000) at Patupaula station for the SWAT model.

Visual observation revealed that the simulated and observed flows matched fairly well, although with slight variations. Calibration and validation matrices for the HEC-HMS model are presented in Table 4. During calibration, NOF was 0.25, NSE was 0.87, PBIAS was 3.58%, and R^2 was 0.93 while during validation, NOF was 0.44, NSE was 0.66, PBIAS was 5.20%, and R^2 was 0.87. These strong correlations indicate that the model can effectively reproduce observed streamflow. The reliability of these values is further validated by the results obtained by [20] for the Patupaula station.

Table 4. Statistical performance metrics during calibration and validation for the SWAT model

	NOF	NSE	PBIAS (%)	R^2
Calibration	0.25	0.87	3.58	0.93
Validation	0.44	0.66	5.20	0.87

B. HEC-HMS Model

Visual inspection determined that during both the calibration and validation periods, observed and simulated streamflow had closer agreements. (Figs. 4(a) and 4(b)). However, the model slightly overestimated the simulated peak flow in certain years.

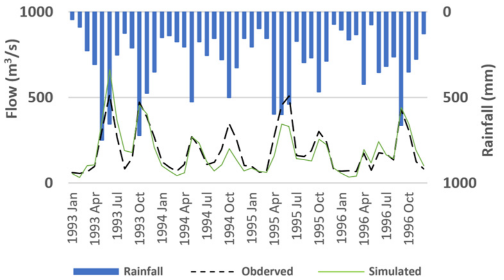


Fig. 4(a) Monthly hydrograph during calibration (1993-1996) at Patupaula station from the HEC-HMS model.

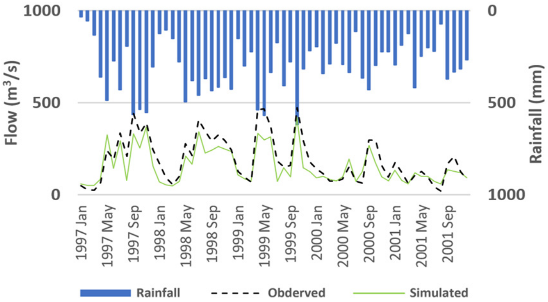


Fig. 4(b) Monthly hydrograph for validation (1997-2000) at Patupaula station from the HEC-HMS model.

The optimized values for the HEC-HMS for KRB are shown in Table 5. The model validation results demonstrated that, from January 1993 to December 2000, the simulated and observed hydrographs had a satisfactory agreement.

Table 5. Fitted values of parameters used for calibration of the HEC-HMS model

Method	**Parameter**	**Units**	**Fitted Value**
Soil Moisture Accounting	Soil Percentage	No units	70
	Groundwater 1	No units	45
	Groundwater 2	No units	82
	Max. Infiltration	mm/hr	10
	Impervious Percentage	No units	0
	Soil Storage	mm	125
	Tension Storage	mm	75
	Soil Percolation	mm/hr	1
	GW 1 Storage	mm	100
	GW 1 Percolation	mm/hr	1
	GW 1 Coefficient	hr	100
	GW 2 Storage	mm	150
	GW 2 Percolation	mm/hr	1
	GW 2 Coefficient	hr	1
Clark Unit Hydrograph	Time of Concentration	hr	28
	Storage Coefficient	hr	40
Recession	Initial Discharge	m^3/s	10
	Recession Constant	No units	0.98
	Ratio to Peak	No units	0.22
Muskingum/Lag	K	hr	1
	x	No units	0.25
	Lag time	min	1176

Table 6 provides the statistics obtained during the HEC-HMS model's calibration and validation phases. The values, R^2 of 0.89 and 0.91, NOFs of 0.33 and 0.41, NSEs of 0.77 and 0.56, and PBIAS of 5.22% and -24.41% were obtained for calibration and validation, respectively. However, despite better performance in the monthly skill metrics for calibration and validation phases, PBIAS indicated an underestimation during the validation phase. These results are supported by the recommended values provided by Moriasi *et al.* [51].

Table 6. Statistical performance metrics during calibration and validation for the HEC-HMS

	NOF	NSE	PBIAS (%)	R^2
Calibration	0.33	0.77	5.22	0.89
Validation	0.41	0.56	-24.41	0.91

C. Intercomparison of Streamflow of SWAT and HEC-HMS Models

For the KRB, the streamflow simulated by HEC-HMS and SWAT was compared with the observed flow. Fig. 5 illustrates the observed and simulated flows during 1993–2000 using both models. Both models exhibited strong performance, although a few discrepancies were noticed. The highest observed monthly flow during June 1993 at "Patupaula" streamflow station was overestimated by 17.4% and 27.6% in SWAT and HEC-HMS models respectively. In addition, the lowest observed monthly flow during March 1998 at Patupaula station was underestimated by 64.7% by the SWAT model and overestimated by 9.4% by the HEC-HMS model. Furthermore, in comparison to SWAT, HEC-HMS was able to record a considerable amount of flood peaks whereas the maximum peak predicted by the HEC-HMS model was 661.7 m^3/s in 1993.

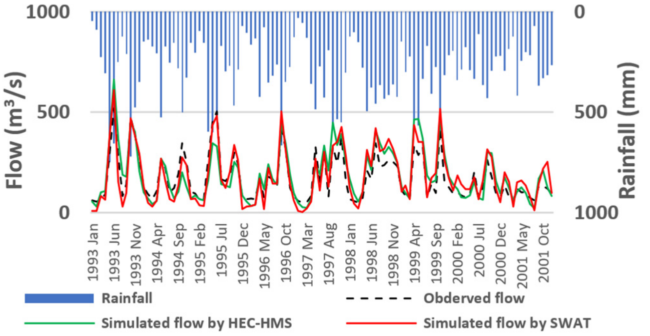
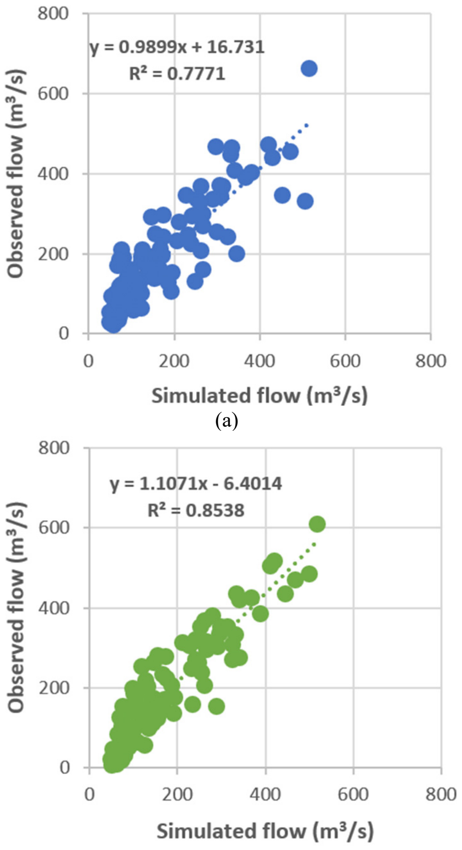


Fig. 5. Observed and simulated hydrographs for the HEC-HMS and SWAT models for the period 1993–2000 of the KRB.

Fig. 6 presents scatter plots for the HEC-HMS and SWAT model simulated and observed flows during the calibration (1993–1996) and validation (1997–2000) periods. The discrepancies underscored the limitations of each model.



(a)

(b)

Fig. 6. Scatter plots for (a) Simulated streamflow from HEC-HMS model and observed flow (b) Simulated flow from the SWAT model and observed flow.

The exceedance probabilities at 10%, 50% and 90% for HEC-HMS and SWAT models were 395, 159, 54.5 m^3/s and 400.5, 148, 29.11 m^3/s, respectively (Fig. 7). Similarly, for observed flow these values were 344.40, 138.98, 65.35 m^3/s.

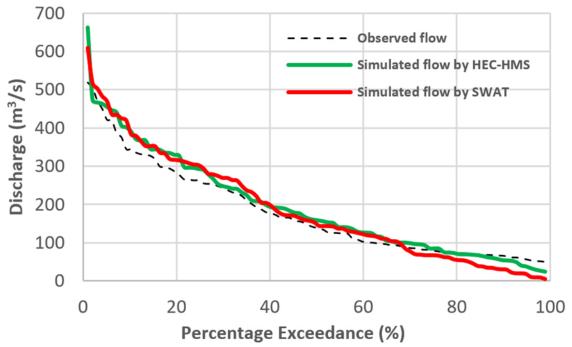


Fig. 7. FDCs for hydrologic model simulated flow and observed flow during period 1993-2000.

Fig. 8 depicts the mean of observed and model simulated mean seasonal flows. In the first inter-monsoon season, simulated flow by HEC-HMS and SWAT models was underpredicted by 3.3% and 4.8% respectively. Further, in the Second Inter-monsoon season, the SWAT model overpredicted by 18%, and in the Southwest monsoon season, the HEC-HMS model overpredicted by 11% as the most significant occurrences. However, in northeast monsoon seasons, simulated flow by SWAT model was similar to the observed flow and only the HEC-HMS model was overpredicted by 9.8%. Nevertheless, seasonal discharge values obtained validated that the SWAT model performed adequately on the seasonal scale in comparison to the HEC-HMS model.

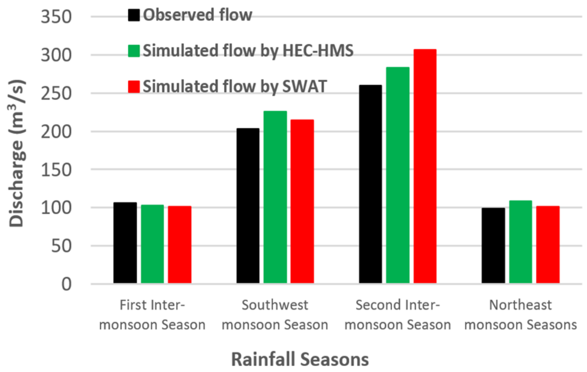


Fig. 8. Depicts mean of observed and model simulated mean seasonal flows.

D. Variability of Model Parameters in Streamflow Simulation

Rainfall data used in the sub-basins of the SWAT model is taken from the nearest rain gauge to the sub-basin centroid. In the HEC-HMS model, weights for the rainfall in sub-basins are determined from the Thiessen Polygon approach [4].

Generally, low flows were predicted by both models with a reasonable level of accuracy. However, in several years, high flows (flood peaks) were overestimated by SWAT and HEC-HMS models. The model results can be improved if several other auxiliary observations can be included in the model (eg: evapotranspiration). The model conceptualization and parameterization could be attributed to discrepancies in flow simulations. Accounting flood peaks simulated by these models could lead to inaccuracies in designing dams, spillways, and other kinds of hydraulic structures in the KRB. For other practical applications such as flood forecasting, it is recommended to use sub-daily simulation results (eg: 30 min, hourly). Adjustments in the model parameters based on observed data may cause uncertainties because they heavily depend on the expertise and judgment of the modeler. The subjective nature of the manual calibration, which leads to selected parameter variability, observation data, model structure, and model algorithms are some main factors that contributes to model uncertainty.

IV. CONCLUSION

This study focused on the Kalu River, which is the second-largest river basin by discharge volume in Sri Lanka, to evaluate the applicability of the SWAT and HEC-HMS models. The present study was conducted from the 1990-2000 period with both models calibrated and validated at the Patupaula hydrological station. The statistical performance of each model was evaluated using NOF, NSE, PBIAS, and R^2. The Flow Duration Curves suggest that the HEC-HMS model captures low flows reasonably. Neither of the models was capable of capturing high flows. We recommend the use of both HEC-HMS and SWAT models since they have shown varied performance in different flow conditions and seasonal scales. Overall, both models can generally capture the hydrology of the KRB.

CONFLICT OF INTEREST

The authors declare no conflict of interest

AUTHOR CONTRIBUTIONS

Conceptualization, M.B.G. and U.R.; methodology, U.S., R.P., R.D.H., D.M.A., R.M., and S.H.; software, U.S., D.M.A., and R.M.; validation, R.M., M.B.G., and U.R.; formal analysis, U.S. and R.P.; resources, R.D.H. and U.R.; data curation, U.S. and S.H.; writing—original draft preparation, U.S.; writing—review and editing, M.B.G., H.M.A., and U.R.; supervision, M.B.G., H.M.A. and U.R.; project administration, U.R.; All authors have read and agreed to the published version of the manuscript.

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