Science & Technology Development Journal, 24(3):2123-2133
Open Access Full Text Article

Research Article

Evaluating two conceptual hydrological models: LST and NAM

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ABSTRACT
Rainfall-runoff models are essential applications for water resources researches. A large number of models have been proposed and developed. Comparisons among models are helpful for researchers to have better choices for their studies of catchment water researches. This study focused on performance evaluations, and comparisons between the LST and NAM lumped conceptual rainfall-runoff models. Two models were applied to simulate runoffs of three catchments in the upper Dong Nai river basin: Phuoc Hoa, Ta Pao, and Phu Hiep. We used the data from 1984-1988 and 1989-1991 to calibrate and validate the Phuoc Hoa catchment, respectively. Those for Ta Pao and Phu Hiep catchments were 1988-1996 and 1997-1999. The results showed that both models performed well in the catchment monthly runoff simulation with NSE and R^2 values greater than 0.90 for Phuoc Hoa and Phu Hiep stations and greater than 0.87 for Ta Pao station. The NSE and R2 by daily runoff simulations for Phuoc Hoa and Phu Hiep were approximate 0.90 except for the Phu Hiep runoff by the NAM model. That for Ta Pao was approximate 0.80. The obtained RSR and PBIAS are respectively lower than 0.50 and 10.00% in almost all simulations. Significantly, the LST model resulted in relatively better statistical performances than the NAM model in almost all statistical fitness values. The study would provide a noteworthy introduction of a good runoff simulation tool to hydrological studies in the future.
Key words: NAM, LST, conceptual lumped model, Be, La Nga

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History
- Received: 2021-07-11
- Accepted: 2021-08-31
- Published: 2021-09-08

DOI : 10.32508/stdj.v24i3.3219

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INTRODUCTION

Rainfall-runoff models play an essential water resources researches. Traditionally, rainfall-runoff models are divided into three types: empirical models, conceptual models, and physical-based models. In terms of spatial consideration, they are classified as lumped and distributed models. The lumped conceptual models have proved to be a good choice for numerous hydrologists due to their simplicity and effectiveness in runoff estimation [1].

A large body of literature has investigated in comparison between hydrological models. Refsgaard and Knudsen compared performances of three hydrological models, including the NedborAfstromnings Model (NAM), the MIKE-SHE, and the Hybrid Water Balance Model (WATBAL) [2]. The study applied in three catchments and concluded that the NAM model is a suitable tool for a catchment with homogeneous climatic data, while the distributed models were better applied for the ungauged catchment. In 2008, Anh et al. tested three lump conceptual models, namely NAM, FEH (Flood Estimation Handbook), and TVM tool developed by their own [3]. The models have employed the Bradford catchment. The authors found that the NAM model had advantages because the model can simulate continuous data even though the catchment did not handle the intermediate flow well. In the same year, Nghi et al. published a paper comparing NAM and XINANJIANG hydrologic models in runoff simulation application for Nong Son catchment, Vietnam [4]. The results showed that the model efficiency performance of the NAM model was slightly higher than that of the XINANJIANG model. Recently, Wakigari valuated three conceptual models, namely Veralgemeend Conceptueel Hydrologisch (VHM), Water Engineering Time Series PROcessing (WETSPRO), and NAM models applying to Guder catchment in the upper Blue Nile basin [5]. The results showed that the NAM model gave better performance than those by VHM and WETSPRO models. Most studies concluded that the conceptual lump model showed superior from the point of view of economic feasibility and the simple technique. The NAM model resulted in better statistical performances in most all related studies.

The Long-and-short-term runoff model (LST model) is a conceptual lump hydrological model. It has been successfully applied in numerous studies. For example, Kadoya and Tanakamura successfully applied the LST model for runoff forecasting in the Osaka dam [6]. Nagai and Yamoto got good results of real-time flood forecasting in the Yoshii River basin in Japan by using the LST model [7]. Islam et al. employed the LST

VNU-HCM Press

Cite this article : Hang N T T, Tuan P B, An D T T, Nga T N Q. **Evaluating two conceptual hydrological models: LST and NAM.** *Sci. Tech. Dev. J.;* 24(3):2123-2133.

model to simulate flood runoff in six mountain basins in Okayama Prefecture in Japan. The results showed that the LST model performed well for all basin simulations[8]. Another study by Kudo et al. indicated that the LST model integrated with Particle filtering was a good tool for flood runoff predicting[9]. However, no research comparing performances with other hydrological models has been found. This paper will examine the performances of the LST model compared to those of a well-known NAM model in runoff estimation applied to the Phuoc Hoa, Ta Pao, and Phu Hiep stations in the upper Dong Nai river basin, Vietnam.

MATERIALS-METHODS

LST model

LST model, developed using the FORTRAN language by the author, is a conceptual rainfall-runoff model[8]. The model contains three tanks, the top tank is divided into two layers (Figure 1). The model structure is shown in Figure 1, in which, S_1, S_2, S_3, S_4 are volumes of the tanks or tank layer (mm); R is average basin rainfall (mm); E_j is evaporation (mm); f is surface infiltration (mm); g is underground layer infiltration amount (mm); Q_1 is the surface flow (mm); Q_2 and Q_3 are subsurface flow (mm); Q_4 and Q_5 are underground flow (mm).
To simulate the catchment runoffs, in addition to the requirement of precipitation and evapotranspiration data, fifteen parameters need to be defined, including:

- Runoff coefficients: a_1, a_2, a_3, a_4, a_5
- Infiltration coefficien: b_1, b_2, b_3
- The heights of side outlets: Z_1, Z_2, Z_3
- The initial storage volume of the tanks: S_1, S_2, S_3, S_4.

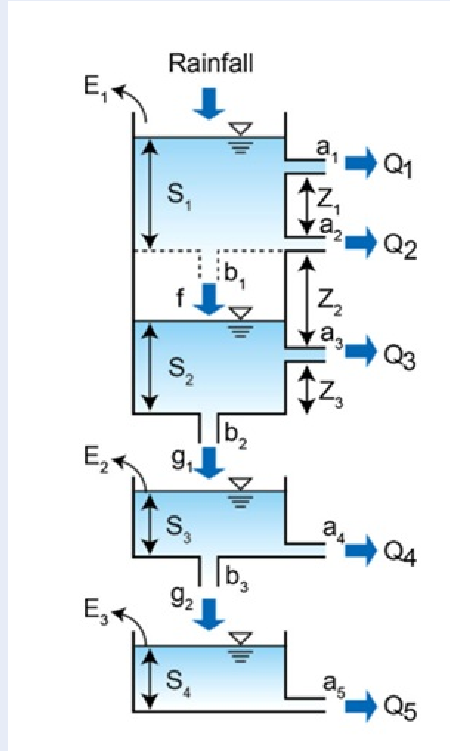

Figure 1: LST model structure[10]

NAM model

NAM, a module of MIKE software developed by DHI, is a lumped conceptual model for simulating the runoff of a catchment. The model structure contains four tanks to present the hydrological process of a catchment (Figure 2). They are snow, surface, subsurface, and groundwater tanks. The snow storage is not considered in this study as the study catchments are in a tropical region. Surface storage represents precipitation interception. The root zone of the soil is described by subsurface storage represents. The groundwater storage represents water under the rock layer. By default, the NAM model considers nine parameters to be determined. The model parameters are adjusted in calibration to achieve the best possible agreements between the simulated and the observed flows. The model requires a minimum of three-year data to get the more reliable model results[11]. Nine default parameters of NAM are as follows: Maximum water content in surface storage (U_{max}); (2) Maximum water content in root zone storage (L_{max}); (3) Overland flow runoff coefficient (CQOF); (4) The time constant for routing interflow (CKIF); (5) Time constants for routing overland flow ($CK_{1,2}$); (6) Root zone threshold value for overland flow (TOF); (7) Root zone threshold value for interflow (TIF); (8) The time constant for routing base flow (CKBF); (9) Root zone threshold value for groundwater recharge (TG). These parameters can be manually or automatically determined. In this study, they are automatically determined using optimization tools in the model.

Study sites

In this study, we investigated two river catchments, namely Be and La Nga. Be river catchment locates on the right side of the Dong Nai river system catchment. It covers four provinces, including DakNong, Binh Phuoc, Binh Duong, Dong Nai. The catchment area is about 7600 km^2. La Nga river originates from Di Linh Plateau with a total catchment area of nearly 4100 km^2. The catchment is between the longitudes

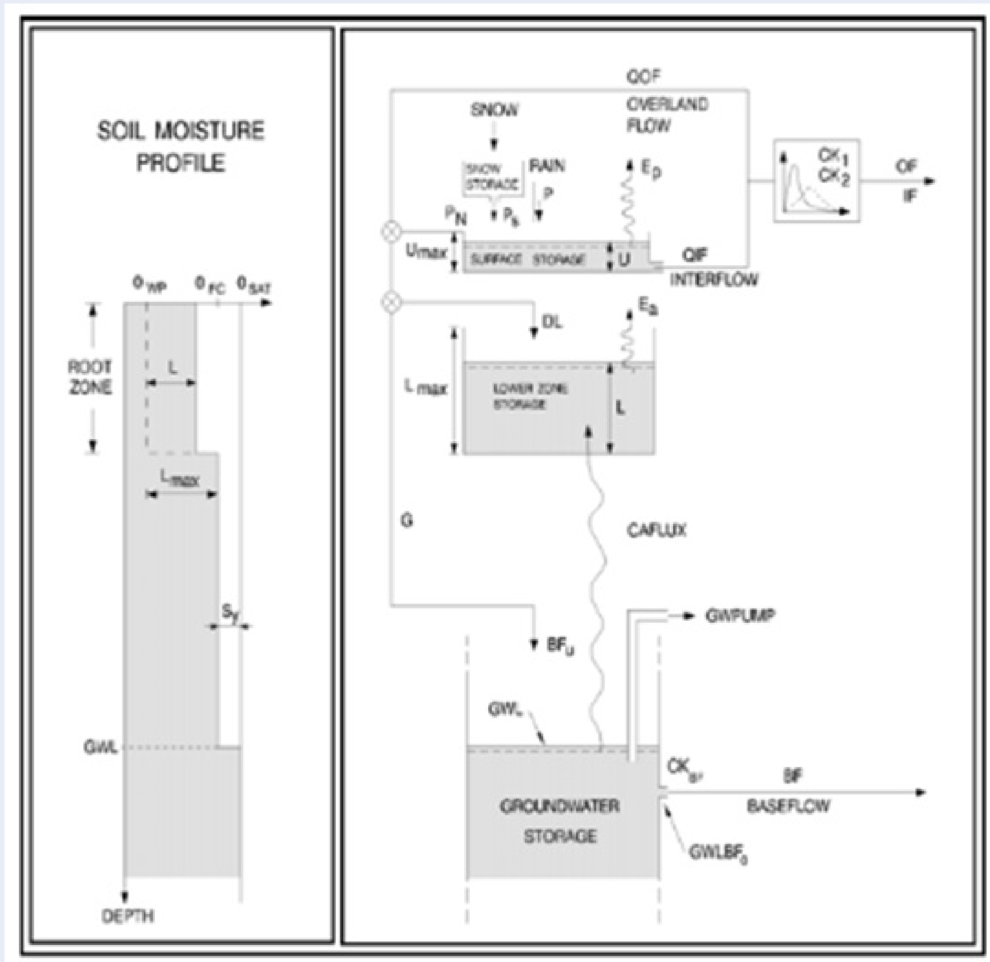

Figure 2: **NAM model structure.**

of 107^{o}13' and 108^{o}16' E, and the latitudes of 10^{o}91' and 11^{o}78' N, covering Lam Dong, Binh Thuan, and Dong Nai provinces. In this study, the upper part of Be river catchment at Phuoc Hoa gauge with an area of about 6000 km^2 was considered (Figure 3a). For the La Nga river catchment, we investigated the flows at Ta Pao and Phu Hiep, the areas of which are about 2034 km^2 and 3763 km^2, respectively (Figure 3b)

Both study sites are in the upper Dong Nai river basin, having a tropical monsoonal climate regime. There are two contrasting seasons, namely rainy and dry seasons. The precipitation amount of the rainy season, which lasts from May to October, accounts for about eighty-five percent of the total annual precipitation, whereas the rest fifteen percentage of precipitation occurs in the dry season, which lasts from November to April of the following year.

According to data collected from the Southern Regional Hydrometeorological Center, the average annual precipitation of the Be river catchment is around 2250 mm, which varies from 1700 in the plain areas to 2700mm in the mountain areas. The average temperature is about 25.5-26.7°C. The minimum and maximum temperatures are relatively 17.3 and 36.6 °C, respectively. The minimum, maximum and annual average humidity are 72.5%, 85%, and 78.1%, respectively. The average annual sunshine duration ranges between 2500 and 3000 h, and the annual evaporation amounts to 1100 mm. The minimum, maximum, and average annual precipitation of the La Nga river catchments are about 2100, 3000, and 2250 mm/year, respectively. These figures for temperatures are 21.8, 25.7, and 22.2 °C. The humidity varies from 71 to 90%, and the average is approximately 81.4%. The annual evaporation amounts to 823.5 mm, and the annual sunshine duration is about 2200 hours. The average annual flow of Be river catchment at Phuoc Hoa station is about 7.13×10^9 m^3. These figures for Ta

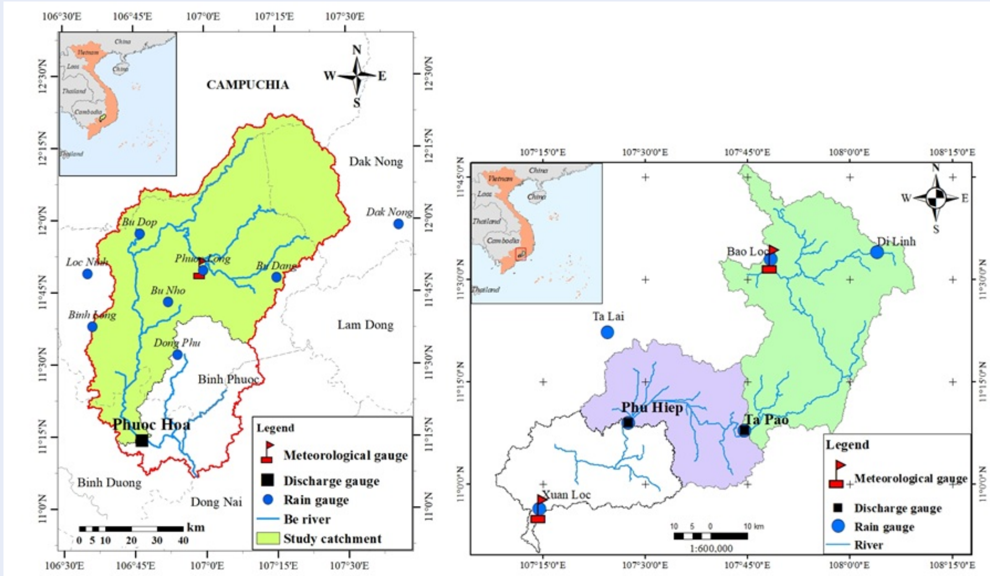

Figure 3: **Maps of the study catchments: Be (left) and La Nga (right).**

Pao and Phu Hiep catchments are 2.37×10^9 m^3 and 4.01×10^9 m^3, respectively.

Data

This study used the data periods of 1984-1988 and 1989-1991 for calibration and validation of Be river catchment, respectively. The respective periods for calibration and validation in La Nga catchments are 1987-1995 and 1996-1999. The following types of data were used in the simulation: (1) daily measured precipitation at rain gauges; (2) monthly meteorological data of temperature, wind speed, humidity, sunshine hours to estimate evapotranspiration using FAO 56 Penman-Monthie approach; (3) daily runoff for calibration and validation. We used precipitation data of nine rain gauge stations in Be river catchment, including Binh Long, Bu Dang, Bu Dop, Bu Nho, DakNong, Dong Phu, Loc Ninh, Phuoc Hoa, Phuoc Long (Figure 3a). Those in the La Nga river catchment are Ta Pao, Bao Loc, Xuan Loc, Ta Lai, Di Linh (Figure 3b). We collected meteorological data at Bao Loc and Xuan Loc stations for La Nga river catchment and Phuoc Long station for Be river catchment. The measured discharges at Ta Pao and Phu Hiep stations of La Nga river catchment, at Phuoc Hoa station of Be river catchment were compared with the simulated.

Model performance evaluation

The model performance is assessed based on the statistical analysis of the simulated and measured discharge agreement. For comparing the model performances between two models in this study, we used four evaluation coefficients. They are Nash - Sutcliffe efficiency index (NSE) [12], percentage of error (PBIAS), the coefficients of determination (R^2), and rate of observed standard deviation (RSR). These coefficients are formulated as [13] and described as follows:

$$NSE = 1 - \frac{\sum_{i=1}^{n}\left(Q_{o,i}-Q_{s,i}\right)^2}{\sum_{i=1}^{n}\left(Q_{o,i}-\bar{Q}_o\right)^2} \quad (1)$$

$$R^2 = \left[\frac{\Sigma\left(Q_{o,i}-\bar{Q}_o\right)\left(Q_{s,i}-\bar{Q}_s\right)}{\sqrt{\sum_{i=1}^{n}\left(Q_{o,i}-\bar{Q}_o\right)^2\sum_{i=1}^{n}\left(Q_{s,i}-\bar{Q}_s\right)^2}}\right]^2 \quad (2)$$

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sqrt{\sum_{i=1}^{n}\left(Q_{o,i}-Q_{s,i}\right)^2}}{\sqrt{\sum_{i=1}^{n}\left(Q_{o,i}-\bar{Q}_s\right)^2}} \quad (3)$$

$$PBIAS = \frac{\sum_{i=1}^{n}\left(Q_{o,i}-Q_{s,i}\right)}{\sum_{i=1}^{n}Q_{o,i}} \times 100\% \quad (4)$$

where n is the number of data, $Q_{o,i}, Q_{s,i}$, are measured and simulated of the ith day; $\bar{Q}_o, \bar{Q}_s$ are the average of measured and simulated discharges, respectively.

The Nash - Sutcliffe efficiency (NSE) varies from $-\infty$ to 1. An optimal agreement between simulation and measurement is achieved when NSE=1. Values greater than 0.50 are evaluated as acceptable performance levels, whereas values less than 0.50 indicate unacceptable performance. The coefficient of determination, R^2, examines the correlation between the measured and the simulated. R^2 ranges between 0.00 and 1.00. The higher value indicates the higher correlation. The rate of observed standard deviation (RSR) ranges between 0.00 to +∞. It has an excellent value of 0.00, indicating the best fit between simulated and measured. The percentage of error (PBIAS) measures the water balance error. The lower values of PBIAS and RSR, the better performances they indicate.

RESULTS

Model calibration and validation

The calibration procedures for both catchments were automatically carried out using the global optimization techniques integrated with the models. The models were calibrated for 1984-1988 for Phuoc Hoa station and 1988-1996 for Ta Pao and Phu Hiep stations. These respective periods for validation were 1989-1991 and 1997-1999. The optimized parameter sets are shown in Tables 1 and 2.

There is evidence from the two tables that there were significant differences among optimized parameter values for three catchments. However, three catchments have similar climate regimes and topographies in the highland areas of the Dong Nai river basin. For example, the achieved TOP parameter of the NAM model for Be river catchment was 0.733, while those for the Ta Pao and Phu Hiep of La Nga basin were 0.40 and 0.96, respectively. TIP parameter values were 0.617, 0.227, and 0.740 for Phuoc Hoa, Ta Pao, and Phu Hiep catchments correspondingly. Those values of the TG parameter were 0.063, 0.840, and 0.134.

Similarly, the obtained parameters of the LST model were considerably distinguishing among the three catchments. For example, the values of the a_1 parameter were obtained as 0.0020, 0.0073, and 0.0012 for Phuoc Hoa, Ta Pao, and Phu Hiep catchments. The respective values of a_2 were 0.0563, 0.0917, 0.0312. These figures for b_3 and Z_1 parameters were 0.0041, 0.0078, 0.0145, and 167.94, 7.36, 190.29 mm, respectively. In general, some parameter values were obtained as double, triple, or more than ten-time differences of a catchment compared to the other.

Daily and monthly flow performance

The daily observed and simulated flows are presented in Figure 4. The right-side graphics are the accumulated daily flows of measurement and simulation by the NAM and LST models. We can see that the simulated discharge matched well with the measured. In general, both models performed well in runoff simulations of three study catchments. The graphical performances were comparable between the two models during calibration and validation periods. It is not easy to see the differences between the two simulated hydrographs. However, the accumulated flows by the LST model are slightly closer to the observed than those by the NAM model. They are presented in the validation period for the Phuoc Hoa station and the calibration period for Ta Pao and Phu Hiep stations.

For statistical performance, it is evident that the LST model performed slightly better than the NAM model. The NSE values of 0.92, 0.81, and 0.90 over daily runoff calibrations were obtained by the LST model for Phuoc Hoa, Ta Pao, and Phu Hiep stations (Table 3). These respective figures by the NAM model were 0.90, 0.79, and 0.85. The differences in obtained R^2 coefficients between the two models were equivalent to the NSE. The RSR values also clearly show better performance for the LST model than those by the NAM model. They are 0.29, 0.47, 0.31 and 0.35, 0.46, 0.39 for respective LST and NAM model, and Phuoc Hoa, Ta Pao, Phu Hiep stations orderly. The water balance coefficient PBIAS is relatively better by NAM model than those by LST model presenting at for La Nga river catchment. They were -3.66% and 0.80% by the LST model and slightly lower -1.26% and 0.53% by the NAM model. For the daily runoff validation, It is obvious that the LST model performed better in Be river catchment with all statical coefficients better than those by the NAM model. They were 0.92, 0.93, 0.28, and 8.00% for NSE, R^2, RSR, and PBIAS indexes. Those by NAM model were 0.87, 0.91, 0.35, and -14.99% respectively. In contrast, the NAM model performed better in RSR and PBIAS coefficients than the LST model for Ta Pao and Phu Hiep stations.

For monthly flow statistics, the LST model represented better than the NAM model in most all indexes of all catchments except the PBIAS values of validations for Ta Pao and Phu Hiep stations (Table 4). The NSE and R^2 values were mainly higher than 0.95 for Phuoc Hoa and Phu Hiep stations. The NSE value was approximately 0.96 for both calibration and validation of Phuoc Hoa catchments. Those for Phu Hiep catchment were 0.96 and 0.94. The R^2 values are slightly higher of 0.96, with 0.97 for Phuoc Hoa station and 0.95 for Phu Hiep station in calibrations and validations. These values obtained by the NAM model are slightly lower. The RSR values by the LST model also performed better than the NAM model for three catchments in both calibrations and validations with the values obtained by LST model calibration were 0.20, 0.24, and 0.23 for Phuoc Hoa, Ta Pao, and Phu Hiep, respectively. The obtained values by the NAM model were 0.21, 0.36, and 0.29. Similar to the daily runoff, the achieved PBIAS coefficients by the NAM

Table 1: Optimal calibrated parameters of the NAM model for three catchments

No.	Parameters	Unit	Catchments		
			Be river	Ta Pao	Phu Hiep
1	U_{max}	mm	17.7	19.4	19.7
2	L_{max}	mm	290	297	226
3	CQOF	-	0.289	0.321	0.137
4	CKIF	hour	712.4	284.9	231.2
5	CK1,2	hour	49.6	48.6	41.6
6	TOP	-	0.73	0.40	0.96
7	TIP	-	0.617	0.227	0.740
8	CKBF	hour	1008	1194	1012
9	TG	-	0.063	0.840	0.134

Table 2: Optimal calibrated parameters of the LST model for three catchments

No.	Parameters	Unit	Catchment		
			Be river	Ta Pao	Phu Hiep
1	A1	-	0.0020	0.0073	0.0012
2	A2	-	0.0563	0.0917	0.0312
3	A3	-	0.0120	0.0301	0.0148
4	A4	-	0.0018	0.0049	0.0044
5	A5	-	0.00046	0.0002	0.0001
6	B1	-	0.1225	0.0959	0.0528
7	B2	-	0.0104	0.0239	0.0221
8	B3	-	0.0041	0.0078	0.0145
9	Z1	mm	167.94	7.36	190.29
10	Z2	mm	382.04	363.95	331.10
11	Z3	mm	197.89	139.63	97.59
12	S1	mm	12.51	11.29	12.69
13	S2	mm	17.01	64.60	116.53
14	S3	mm	206.06	128.22	173.26
15	S4	mm	346.5364	2363.16	2882.86

model for Ta Pao and Phu Hiep station in the validation period were relatively better than those by the LST model.

Water budget

Figure 5 shows the annual water balance in calibration and validation periods of Phuoc Hoa, Ta Pao, and Phu Hiep stations. We can see that the LST model's volume of annual water balance is closer to the observations than those by the NAM model in both calibration and validation years except in the year 1989, when the NAM model performed better. The graphical plots revealed that the NAM model resulted in significant overestimation in 1990 and 1991, while the LST model's water volumes in these years were close to the observation. The annual simulated flows in both models were higher than the annual observed in 1984, 1985, and 1987. However, those by the NAM model were also higher than those by the LST model.

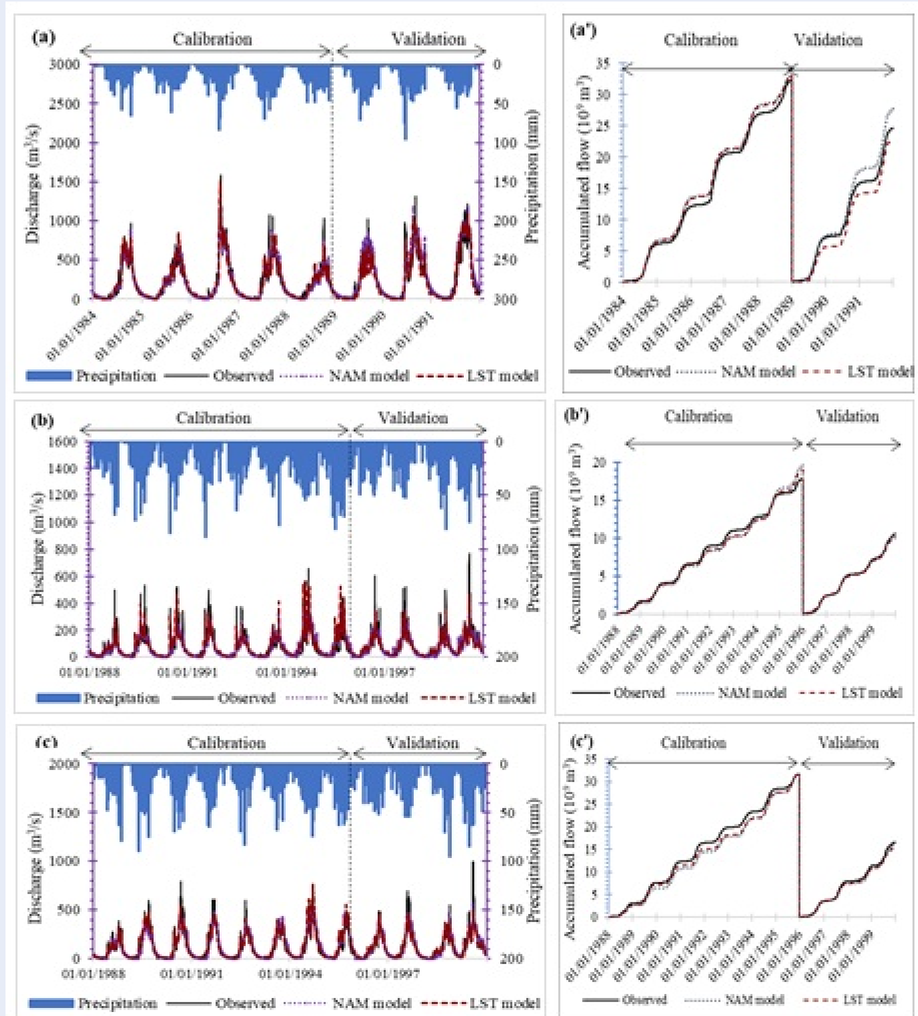

Figure 4: **Daily and accumulated Observed and simulated flows at three stations: Daily flows at Phuoc Hoa (a), daily flow at Ta Pao (b), daily flow at Phu Hiep (c); accumulated flows at Phuoc Hoa (a'), accumulated flow at Ta Pao (b'), accumulated flow at Phu Hiep (c')**

For the Ta Pao catchment, the LST model's results showed better than those by the NAM model in 1988, 1990, 1993, 1994, 1995, 1998, while the NAM model showed better in 1992, 1996, 1997, 1999. The maintaining years show comparable results between the two models. The annual flows of Phu Hiep catchment in 1989, 1993, 1995, 1998 obtained by the LST model are closer to the observation than those obtained by the NAM model. However, the against results were found in 1988, 1990, 1991, 1992, 1994, 1996, 1997, and 1999.

Figure 6 shows the average monthly flow over the combined durations calibration and validation. The average monthly flow in the Be river catchment shows that the LST model performed better than the NAM model over the year except for some dry months of March, April, and May. Similarly, the performance of the LST model for Phu Hiep station was also superior to that of the NAM model in all months except July. However, the LST model's average monthly flow at Ta Pao station was slightly worse than the NAM model in most months except April, August, and December.

DISCUSSION

The current study was designed to compare the performances of two conceptual hydrological models, NAM and LST. This study shows that both models have sensitive parameters obtained with significant distinguish values among the catchments, while all study catchments are in the upper area of the Dong

Table 3: Statistical measures resulted from NAM and LST models for daily runoff simulations

Periods	Statistical measurements	Phuoc Hoa		Ta Pao		Phu Hiep	
		NAM	LST	NAM	LST	NAM	LST
Calibration	NSE	0.90	0.92	0.79	0.81	0.85	0.90
	R2	0.90	0.92	0.80	0.81	0.85	0.90
	RSR	0.35	0.29	0.46	0.47	0.39	0.31
	PBIAS	-4.95%	-1.96%	-1.26%	-3.66%	0.53%	0.80%
Validation	NSE	0.87	0.92	0.86	0.87	0.84	0.89
	R2	0.91	0.93	0.86	0.83	0.85	0.89
	RSR	0.35	0.28	0.27	0.41	0.28	0.37
	PBIAS	-14.99%	8.00%	-1.26%	4.17%	2.90%	7.22%

Table 4: Statistical measures resulted from NAM and LST models for monthly runoff simulations

Periods	Statistical measurements	Phuoc Hoa		Ta Pao		Phu Hiep	
		NAM	LST	NAM	LST	NAM	LST
Calibration	NSE	0.96	0.96	0.87	0.88	0.91	0.95
	R2	0.96	0.96	0.89	0.89	0.91	0.95
	RSR	0.21	0.20	0.36	0.24	0.29	0.23
	PBIAS	-2.59%	-2.02%	-4.51%	-3.53%	0.85%	0.80%
Validation	NSE	0.94	0.96	0.95	0.93	0.93	0.93
	R2	0.96	0.97	0.95	0.97	0.93	0.95
	RSR	0.25	0.20	0.27	0.26	0.27	0.27
	PBIAS	-12.54%	8.07%	-1.26%	4.17%	2.95%	7.22%

Nai river basin. Nevertheless, they have similar climate regimes and topographic conditions. Some parameters are low in this catchment, but they are high in another catchment. For example, the NAM model's TOP, TIF, Tg parameters are double, triple, or more than ten-time differences among catchments.

Similarly, the optimized parameter a_1, a_2, b_3, Z_1 were also different among the catchments. There is a possible explanation for this result. More than one parameter set can result in the equivalent performances of runoff simulation due to the compensation among the model parameters, as explained by Zhang et al.[1]. This point is also an appropriate explanation for this study.

Another important finding was that both models result in good fitness between the observations and simulations. There was no significant visual difference between simulated hydrographs by NAM and LST model. A minor variation between daily accumulated flow by two models was found. Both models performed high fitness between simulated, and the observed with almost all statistical performance values. The results presented that NSE and R^2 greater than 0.90 were achieved in all simulations except for daily runoff in the Ta Pao catchment. RSR and PBIAS values achieved by the two models were lower than 0.50 and 10.00% for all calibrations and validations over three catchments. According to Moriasi et al. (2007), the performances are evaluated as "very good" for all study simulations at coefficients (13). The findings confirm the performances of the NAM model in previous studies[3,14,15]. Surprisingly, the LST model was found to have slightly better statistical performances than the NAM model. It is presented in the results

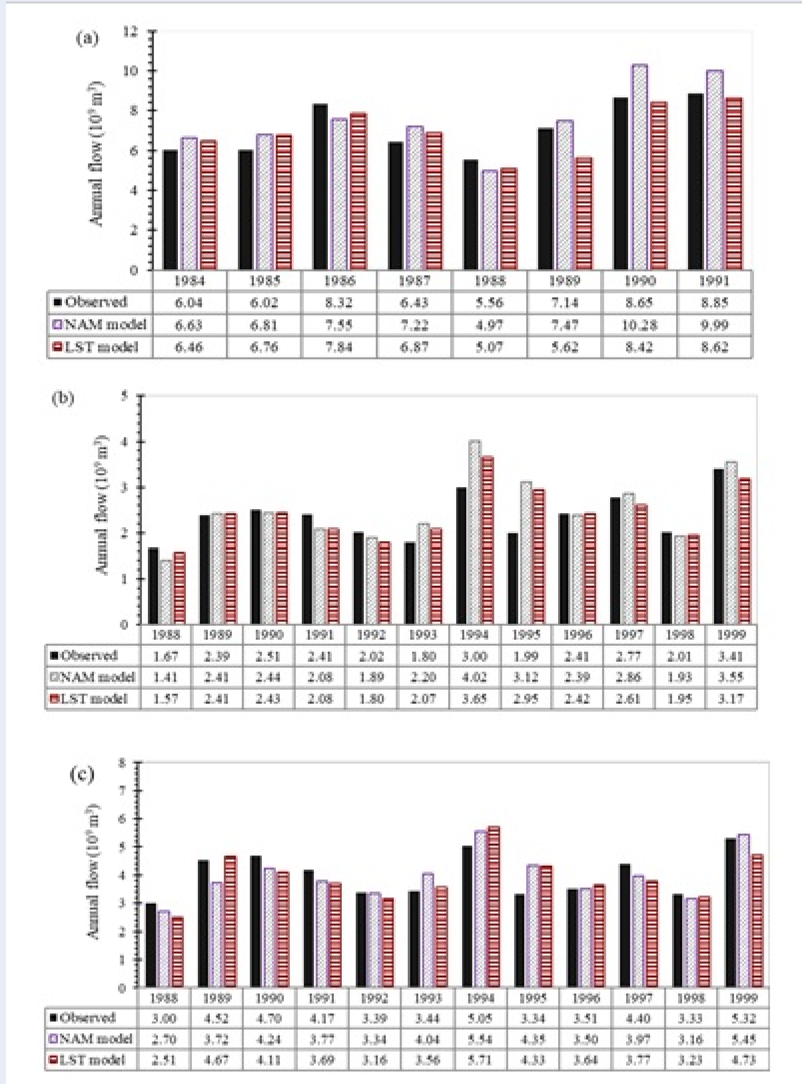

Figure 5: Annual water budget in calibration and validation periods at Phuoc Hoa (a), Ta Pao (b), and Phu Hiep stations (c)

of Be river catchment with all obtained coefficients by LST model better than those by NAM model. Similar results were obtained for coefficients of monthly runoffs at Ta Pao and Phu Hiep stations.

The findings may help us to understand the performances of the LST rainfall-runoff model in daily flow simulation. The hydrological researchers can consider this model a good tool for catchment runoff estimation, which is fundamental for water resources studies. Further research should be done to investigate the comparations the two models with the physical-based and distributed models.

CONCLUSIONS

The paper has discussed LST and NAM model performances in runoff simulations for Phuoc Hoa, Ta Pao, and Phu Hiep catchments in the upper Dong Nai river basins. The study has shown that both models have sensitive parameters. Some achieved parameters such as a_1, a_2, b_3, Z_1 of the LST model, and TOP, TIF, Tg parameters of NAM model were significantly different among catchments.

Both LST and NAM models performed well for daily and monthly runoff in calibrations and validations. The NSE and R^2 were greater than 0.95 for monthly simulation and slightly greater than 0.90 for daily simulation at Phuoc Hoa station. The respective figure for

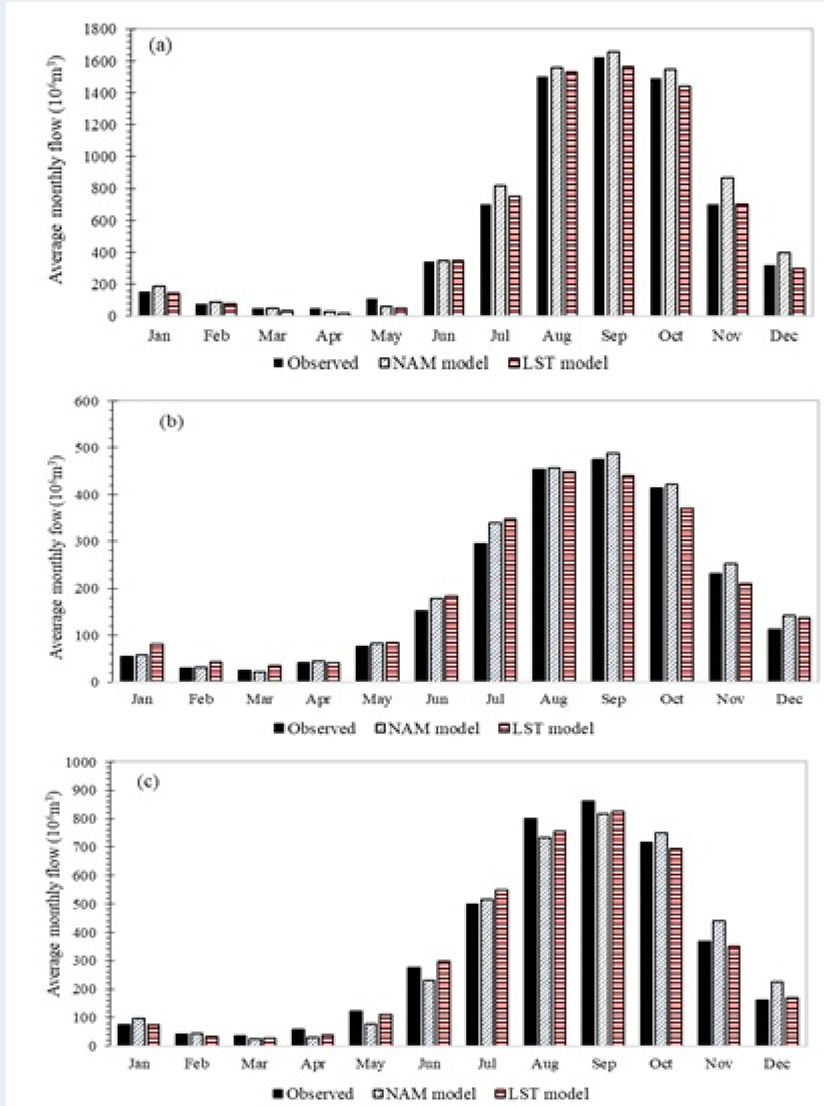

Figure 6: Average monthly water flow over calibration and validation periods at Phuoc Hoa (a), Ta Pao (b), and Phu Hiep (c) stations

daily data was 0.90. The achieved values for Ta Pao and Phu Hiep stations were relatively lower. However they were performed well according to criteria by Moriasi et al.[13]. Similar tendencies were obtained with the RSR coefficient. The water balance coefficient, PBIAS, ranged from 14.99 to 7.22 % for daily simulation and from -12.54 to 7.22% for monthly simulation. Significantly, the LST model results were slightly better than those of the NAM model in statistical fitness performances of calibration and validation and the water budget.

The findings of this study suggest that the LST model can be confidently considered for catchment water resources studies in the future. However, future research is needed to compare the distributed and physical-based models in runoff simulations. That helps researchers have a good choice of rainfall-runoff tools in water resources investigations.

LIST OF ABBREVIATIONS

LST: Long-and-short-term

NAM: NedborAfstromnings Model

NSE: Nash — Sutcliffe efficiency

R^2: The coefficients of determination

PBIAS: Percentage of error

RSR: Rate of observed standard deviation

COMPETING INTERESTS

The authors declare that they have no competing interests.

ACKNOWLEDGEMENTS

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number C2020-18-17.

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