OPTIMIZATION OF RAINFALL SPATIAL VARIABILITY FOR DAILY STREAMFLOW ESTIMATION WITH A MONTHLY WATER BALANCE MODEL

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April 2020

DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgment any material previously submitted for the a Degree or Diploma in any other University or institute of higher learning and to the best of knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in text.

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Optimization of Rainfall Spatial Variability for Daily Streamflow Estimation with a Monthly Water Balance Model

ABSTRACT

Precipitation varies significantly over space and time within a watershed. Precipitation has a vital role in determining surface hydrological processes because of its influence on streamflow estimations using mathematical models. Though monthly rainfall data provides ease of access due to availability and affordability, daily data is the preferred option of engineers, planners and water managers. This is because daily time resolution is considered as a unit which reasonably represent the catchment time lag. If a water model calibrated using monthly data could estimate daily streamflow from a watershed, then this would be of immense value for sustainable water resources management. The three-parameter monthly water balance model (3PMWBM) proposed by (Dissanayake, 2017) has demonstrated the capability with an application on 2 watersheds in Sri Lanka while using Thiessen averaging method for rainfall input. Wijesekera and Musiake (1990a, 1990b) had optimized both rainfall station weights and model parameters for improved streamflow estimations by enabling the calibration of point rainfall measurements to generate a spatially averaged rainfall to reflect the response of the corresponding watershed. The study objective is to estimate streamflow in daily timescale using a monthly water balance model while optimizing the spatial variability of rainfall leading to enhanced water security and sustainable water management. Daily data from 2005 to 2014 of 4 rainfall stations of Badalgama watershed (1360 km^2) in Ma Oya Basin, Sri Lanka are used to evaluate the streamflow predictions with the 3PMWBM when rainfall station weights are optimized. The 3PMWBM was developed, calibrated and verified with and without optimizing the rainfall gauging station weights. A spreadsheet tool and an object oriented modelling tool was used for the model development. Mean Ratio of Absolute Error (MRAE) was selected as the objective function during calibration and verification. The high, medium and low flow determined from observations and annual water balance were also were used during evaluation. The optimum value based on literature and analysis for Sc, C and k are 908, 2.5 and 0.69 respectively for monthly model. The MRAE calibration and verification results obtained at consecutive steps 0.41,0.409 and 0.36 and 0.60,0.62,0.50 i.e. optimizing model parameters, optimizing rainfall weights, optimizing model parameter and rainfall weights at the same time Thiessen weights are (0.26,0.19,0.20,0.35), (0.20,0.16,0.26,0.38) and (0.23,0.14,0.27,0.36) respectively for Ambepussa, Andigama, Aranayake and Eraminigolla stations. Daily streamflow estimations in Badalgama watershed using 3PMWBM with the optimization of rainfall station weights with optimum average MRAE 0.64. The study found that spatial variability of rainfall can significantly affect model results about 17% improvement in average MRAE at monthly scale when station weights and parameters are simultaneously optimized and under same case when the model is used for daily streamflow estimation, up to 8% improvements in average MRAE are noticed.

KEYWORDS: Daily streamflow estimation with monthly model, Station Weights, Rainfall spatial variability

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LIST OF ABBREVIATIONS

Abbreviation	Description
2PMWBM	Two Parameter Monthly Water Balance Model
3PMWBM	Three Parameter Monthly Water Balance Model
AWBM	Australian Water Balance Model
c	Parameter c
CRR	Conceptual Rainfall Runoff
E	Nash–Sutcliffe coefficient
Ef	Nash-Sutcliffe coefficient
ET	Evapotranspiration
FDC	Flow Duration Curve
GR2M	Global Reservoir 2 Parameter Model
GR5M	Global Reservoir 5 Parameter Model
K	Runoff Adjustment Factor
MRAE	Mean Ratio of Absolute Error
MRAE	Mean Ratio of Absolute Error
MSE	Mean Square Root
MWB	Monthly Water Balance
MWB-3	Monthly Water Balance Model with 3 Parameters
MWB-6	Monthly Water Balance Model with 6 Parameters
NAM	Nedbor-Afstromnings mode
NOPEX	A NOrthern hemisphere climate Processes landsurface EXperiment)
NSE	Nash Sutcliffe Efficiency
NSE	Nash-Sutcliffe Efficiency
P (t)	Rainfall
P Models	Precipitation Models
Par	Parameter
PE Models	Precipitation Evaporation Models
PTM	The Pitman model
Q (t)	Runoff
RAEM	Ratio of Absolute Error to Mean
RE	Relative Error
RE	Relative Error
RMSE	Mean Square Root Error
S (t)	Soil Moisture Content
SC	Field capacity of the catchment
SMA	The Sacramento model
TWS	Total Water Storage
USA	United States of America
WBM	Water Balance Model
XNJ	The Xinanjiang model

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