MODELLING STREAMFLOW VARIABILITY IN DRY AND WET ZONE RIVER BASINS IN SRI LANKA USING SATELLITE SOIL MOISTURE DATA

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Degree of Master of Science

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Department of Civil Engineering

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Porf. R. L. H. L. Rajapakse Date

ABSTRACT

Modelling Streamflow Variability in Dry and Wet Zone River Basins in Sri Lanka using Satellite Soil Moisture Data

Streamflow variability is important in basin water resources management to analyze and plan for the present and future hazards and vulnerabilities affecting effective water management. The unique feature of soil to hold the moisture regulates the precipitation falling on its surface generating the variability in streamflow. The lack of extensive data for distributed hydrological models restrains modelers to accurately simulate temporal and spatial variability of streamflow associated with the soil moisture (SM) in basin-scale. The present study is focused on the use of a simple hydrologic model to assess the impact of SM on the generation of streamflow variability in selected dry and wet zone river basins in Sri Lanka and enhance the model accuracy through the use of satellite soil moisture (SSM) data. The wet and dry zone river basins, Kalu Ganga and Kirindi Oya basins, respectively with a diverse streamflow variability were selected for this study. A semi-distributed hydrologic model was developed to model various events using Hydrologic Engineering Centre's Hydrologic Modelling System (HEC-HMS) with soil moisture accounting (SMA) as the loss method. The results obtained from the model are compared with model results forced with soil moisture active passive (SMAP) SM data to assess the impact of antecedent moisture on watershed hydrology.

Events of varying magnitude in terms of discharge and precipitation from both Maha and Yala seasons were selected considering different return period discharge to calibrate and validate the model performance. Both models developed for Kirindi Oya and Kalu Ganga performed well with an average Nash-Sutcliffe Efficiency (NSE) of above 0.73 for calibration and above 0.75 for validation along with average root mean square error (RMSE) and observed standard deviation ratio (RMSE std dev) below 0.55 for calibration and below 0.48 for validation. The average coefficient of determination (R^2) was obtained above 0.80 indicating a strong correlation. Initial use of SSM improved the model performance of the Kalu Ganga basin whereas deteriorated the performance of the Kirindi Oya basin. The performance was further enhanced by optimizing the soil storage and groundwater parameters yielding an average NSE higher than 0.80, an average R^2 of above 0.90 along with an average RMSE std dev below 0.35 in both basins. Further, the average variation in peak discharge and runoff volume was reduced to 6 % and 2 %, respectively for Kirindi Oya and 15 % and 10 %, respectively for Kalu Ganga basins. The overestimated peak discharge and runoff volume were reduced by 28 % and 18%, respectively upon increasing the soil storage parameters whereas the underestimated peak discharge and runoff volume were increased by 37 % and 43%, respectively by decreasing the soil storage parameters.

A minor adjustment in soil storage allowed to manipulate and fine-tune the peak discharge and runoff volume in the basin which substantiates that the runoff is directly associated with the basin SM. The findings of this study can be useful in basins with similar hydrological characteristics to understand the role of SM in runoff generation and for sustainable water management in the basin.

Keywords: Antecedent moisture condition (AMC), Event-based modelling, Soil moisture accounting (SMA), Soil moisture active passive (SMAP)

DEDICATION

I would like to dedicate this work to my

Father and Mother

The biggest treasure of my life who always taught me to do good and work hard. No words can explain their patience and sacrifices beyond everything just to shape my life.

To my amazing two

Sisters

For having faith in me and cheering me every time to work harder.

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LIST OF ABBREVIATIONS

AM	-	Annual Maximum
AMC	-	Antecedent Moisture Condition
CDD	-	Consecutive dry days
CDS	-	Consecutive low-flow days
CWD	-	Consecutive wet days
CWS	-	Consecutive high-flow days
DC	-	Deficit and Constant
DEM	-	Digital Elevation Model
ESA	-	European Space Agency
ESRI	-	Environmental Systems Research Institute
ET	-	Evapotranspiration
FDC	-	Flow Duration Curve
FIT	-	First Inter Monsoon
HEC	-	Hydrologic Engineering Center
HMS	-	Hydrologic Modeling System
IPCC	-	Intergovernmental Panel on Climate Change
LULC	-	Land-use Landcover
MIT	-	Minimum Inter-event Time
NEM	-	North East Monsoon
NSE	-	Nash Sutcliffe Efficiency
PBIAS	-	Percentage Bias
POT	-	Peak Over Threshold
PVE	-	Percentage Streamflow Volume Error
R10	-	Heavy precipitation days

R20	-	Very heavy precipitation days
RAS	-	River Analysis System
RMSE	-	Root Mean Square Error
RMSE std dev	-	RMSE Observed Standard Deviation Ratio
RX1 day	-	Max 1-day precipitation
RX2 day	-	Max 2-day precipitation
RX5 day	-	Max 5-day precipitation
SCS	-	Soil conservation service
SIM	-	Second Inter Monsoon
SM	-	Soil Moisture
SMA	-	Soil Moisture Accounting
SMAP	-	Soil Moisture Active Passive
SPI	-	Standardized Precipitation Index
SSI	-	Standardized Streamflow Index
SSM	-	Satellite Soil Moisture
SWAT	-	Soil and Water Assessment Tool
SWM	-	Southwest Monsoon
SX1 day	-	Max 1-day flow
SX2 day	-	Max 2-Day Flow
SX5 day	-	Max 5-Day Flow