EVALUATION OF CLIMATE ELASTICITY OF RUNOFF BASED ON OBSERVED RAINFALL/ STREAMFLOW DATA AND SIMULATED FUTURE STREAMFLOW USING SWAT MODEL IN KELANI GANGA BASIN

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Degree of Master of Science in
Water Resources Engineering and Management

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July 2020

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Water Resources Engineering and Management

Supervised by

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July 2020

DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my 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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Kariyawasam Katukolihe Gamage Irnika Laksri Siriwardena Date

The above candidate has carried out research for the Masters thesis under my supervision.

……. ……...

Dr. R. L. H. L. Rajapakse Date

Evaluation of Climate Elasticity of Runoff based on Observed Rainfall/ Streamflow Data and Simulated Future Streamflow using SWAT Model in Kelani Ganga Basin

Abstract

Kelani Ganga basin is the 7th largest watershed in Sri Lanka, spanning over 2,292 km^2, with a length of 145 km, and annually discharging 4,225 MCM flow to the sea. The annual average rainfall varies from 2000 mm to 5700 mm while annual average temperature (T_{avg}) varies from 28 ºC to 30 ºC in the basin. The basin currently hosts over 19 % of the country's population and is the primary source of drinking water to over 4 million people living in Greater Colombo. Hence, it is vital to investigate the potential effects of climate change on streamflow in the basin. The present study was undertaken to evaluate Climate Elasticity of runoff based on observed rainfall/ streamflow data and simulated future streamflow using SWAT Model in Kelani Ganga basin, targeting sustainable management of basin water resources in future.

Hydro-meteorological data were collected for 41 rainfall, 10 temperature, and 3 streamflow gauging stations in and around the basin. The initial data checking was carried out and gap filling was performed based on regression analysis for streamflow and Inverse Distance Weighting (IDW) for rainfall and temperature. Root-mean-squared errors (RMSE) were calculated for each month and each percentile to determine the most suitable combination of Alpha of both rainfall and temperature. The $\alpha = 1$ for rainfall and $\alpha = 5$ for temperature were obtained as optimum parameters for the IDW. Additional statistical tests were carried out to identify trends on Climate change using Innovative Trend Analysis (ITA), Mann-Kendall and Sen's Slope tests for rainfall, temperature and streamflow. Decadal averages and deviation from Mean were plotted for all rainfall stations in and around the basin. SWAT model was built to simulate streamflow for the selected duration of 1960 to 2016 and the model was calibrated and validated for the key hydrometric station at Glencourse. The runoff elasticity (ε) is assessed by two methods based on the impact assessment of climate change only and impacts of land surface and climate change, respectively for current and Future Pessimistic Climate Change Scenario for 2040 after incorporating the projected landuse for 2040.

Annual average flow is reduced by 14% from the period of 1960-2016 to the period of 1980-2016 at Glencourse. The runoff to rainfall ratio at Glencourse and Hanwella for the period of 1980 to 2016 are 53% and 55%, respectively. Among 41 rainfall stations, 20 exhibit positive trends, 17 show the negative trends for annual rainfall totals for the all three tests of ITA, Sen's Slope and Mann-Kendall tests. The all selected three hydrometric gauging stations exhibit significant downward trends for the period of 1980 to 2016. An 80 % of the rain gauges in the middle and Upper basin, show significant decreasing trends for high to low rainfall totals for Yala season as ITA analysis for the period of 1980 to 2016. The model calibration and validation were completed at Glencourse for the period 1970 to 1980 and 1982 to 1992, respectively. Mass balance performance Error (Er), Nash–Sutcliffe efficiency (NSE) and coefficient of determination (R^2) are used as multi-objective functions and 8.90 %, 0.65, 0.72 and 9.10 %, 0.69, 0.69 are obtained, respectively for the calibration and validation periods.

1 ºC of temperature increase causes 6.9 % and 7.4 % runoff decrease for current scenario and 0.4 % increase and 1.5 % decrease of runoff for Future Pessimistic Climate Change Scenario as evaluated by two methods, respectively. 1% of rainfall increase causes runoff increase of 0.002 % and 0.370 % for current scenario and runoff increase of 0.005 % and 0.360 % for 2040 as evaluated by two methods, respectively. The flow didn't show significant increase for 2040 with projected landuse at Glencourse gauging station. As the water extraction quantity is significantly high for the districts, namely Colombo and Gampaha, with the highest residential densities with a majority (78%) are living in Kelani Ganga basin, it is recommended to further analyse the water allocation model for better results with practical implementations by considering identified trend after 1995 in future researches for planning and management of water resources in future.

Keywords: Inverse Distance Weighting, Mann-Kendal test, Sen's Slope, Innovative Trend Analysis, Precipitation elasticity, Future Pessimistic Scenario

DEDICATION

Every challenging work needs self-effort as well as the guidance of elders especially those who are very close to our heart.

My humble efforts are dedicated to my loving

father

who is in heaven, was always watching over me and guiding hand of me forever

mother & husband

whose affection, love and encouragement of everyday allowed me to accomplish this success and honour.

Along with the above, this work is also dedicated to my committed and respected

teachers

ACKNOWLEDGEMENT

I would like to convey my sincere and heartfelt gratitude to my research supervisor, Dr. R. L. H. Lalith Rajapakse, Senior Lecturer, Course Coordinator, UNESCO Madanjeet Singh Center for South Asia Water Management (UMCSAWM), University of Moratuwa for giving me an opportunity to continue my research under his invaluable guidance and the continuous support of my study with his patience, motivation and immense knowledge. His energy, vision, sincerity and motivation have deeply inspired me. It was a great privilege and honour to work and study under his guidance. Without his dedicated supervision and continued guidance, this thesis would not be successfully completed within the time frame. During my period, he consistently allowed this research to be my own work, but steered me in the right direction whenever he thought I needed it.

Further, I would like to extend my gratitude for Professor N.T.S. Wijesekera, Senior Professor of UMCSAWM, for his guidance and the encouragement for completing my master and the methodology is being taught to carry out the research and to present the research works as clear as possible on Water Resources Engineering. He was always kind enough to provide the necessary direction and support even with his tight schedules. His sincere and consistent encouragement is greatly appreciated. Then I would like to thank, all the lectures, who conducted postgraduate lectures.

Next, I would also like to thank all staff at UMCSAWM, who encouraged, inspired, supported, assisted, and sacrificed their time and efforts to help my studies of a Master's degree. I am grateful to thanks my colleagues with whom I worked together and always they supported me notwithstanding their own work. Not only that, but also I would like to extend my honest thank to Eng. D. C. S. Elakanda, Project Director, Climate Resilience Improvement Project and Eng. (Mrs). P. A. A. P. K. Pannala, Deputy Project Director (CRIP) for providing me with their support to complete the Master's degree. Moreover, it is my responsibility to thank all the organizations, who provided the data to carry out this study including Mahaweli Authority of Sri Lanka, Irrigation Department, Meteorological Department and survey Department.

Finally, I would like to thank my family, and friends for giving me the strength to finish this thesis in a fruitful manner.

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LIST OF ABBREVIATIONS

Abbreviation	Description
CC	Climate Change
CEB	Ceylon Electricity Board
DEM	Digital Elevation Model
DSWRPP	Dam Safety, Water Resources Planning Project
ETo	Evapotranspiration
FDC	Flow Duration Curve
FIM	First Inter Monsoon
FSL	Full Supply Level
FPM	FAO-56 Penman-Monteith equation
GCM	Globle Climatic Models
GIS	Geographic Information System
HG	Hargreaves equation
HRUs	Hydrological Response Units
ID	Irrigation Department
IDW	Inverse Distance Weighting
IPCC	Intergovernmental Panel on Climate Change
ITA	Innovative Trend Analysis
LHGu	Modified linear regression calibrated HG equations
LIDAR	Light Detecting And Ranging
LTA	Long term Average
LUPPD	Landuse Policy Planning Department

m AMSL	m Above Mean Sea Level
MOL	Minimum Operating Level
MCM	Million Cubic Meters
MK	Mann-Kendall test
NEM	North East Monsoon
NWSDB	National Water Supply and Drainage Board
PET	Potential Evapotranspiration
SD	Standard Deviation
SIM	Second Inter Monsoon
SSSSL	Soil Science Society of Sri Lanka
SSSSL	Soil Science Society of Sri Lanka
SWAT	Soil Water Assessment Tool
SWM	South West Monsoon
T_{avg}	Average Temperature
T_{max}	Maximum Temperature
T_{min}	Minimum Temperature
RCM	Regional Climatic Models
RCP	Regional Concentration Pathways
RMSE	Root-mean-squared errors
UNCED	UN conference on development and Environment
WMO	World Meteorological Organisation