CLIMATE EXTREMES AND PRECIPITATION TRENDS IN KELANI RIVER BASIN, SRI LANKA AND IMPACT ON STREAMFLOW VARIABILITY UNDER CLIMATE CHANGE

K. D .C. R. Dissanayaka

(158554 K)

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Department of Civil Engineering

University of Moratuwa

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K. D. C. R. Dissanayaka

(158554 K)

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

Supervised by
Dr. R. L. H. L Rajapakse

Department of Civil Engineering
UNESCO Madanjeet Singh Centre for South Asia Water Management (UMCSAWM)

University of Moratuwa
Sri Lanka

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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 knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in text.

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Climate Extremes and Precipitation Trends in Kelani River Basin, Sri Lanka and Impact on Streamflow Variability under Climate Change

ABSTRACT

The study region comprises a major river basin in the West of Sri Lanka namely Kelani River basin. The hydrological regime of this river differs significantly from that of the others because the basin features great geographical and climatic diversities over its latitudinal and longitudinal extent. Kelani River is the second largest river in Sri Lanka that originates from the central hills and flows to the west coast through Colombo city. The river basin is bound by northern latitudes from 6°47' to 7°05' and eastern longitudes from 79°52' to 80°13'. The river originates approximately 2,250 m above mean sea level and passes 192 km to reach the Indian Ocean. The river basin experiences an annual average rainfall of about 3,450 mm corresponding to a volume of about 7,860 MCM out of 43% discharges into the sea. However, changes in precipitation and temperature due to the climate change can cause more frequent extremes with extended droughts and floods with further impact to the reservoir storage resulting a significant threat to water resources. Therefore, the present study focuses on climate extremes with reference to the past, present and future behavior of rainfall, temperature and streamflow at watershed scale to identify climate change impact on the spatial and temporal variations of streamflow in the Kelani River Basin.

For this research, basin-wide future hydrology is simulated by using downscaled temperature and precipitation outputs according to RCP Scenarios of the Canadian Earth System Model - version 2 (CanESM2), Statistical Downscaling Model (SDSM) and the Hydrologic Engineering Centre's Hydrologic Modeling System (HEC-HMS). The case study further evaluates the long-term behaviour and trends of the climate extremes based on the observed historical temperature and precipitation data. The findings suggest that the temperature and precipitation extremes are on the rise while the annual average precipitation in the river basin is declining. It is also predicted with the application of statistical downscaling that temperature may rise annually for representative concentration pathways of RCP2.6, RCP4.5 and RCP8.5. The mean explained variance are 67, 86 and 13% for temperature maximum, temperature minimum and precipitation respectively, for calibration with NCEP predictors. During calibration, the R^2 value of the monthly and seasonal sub-model of RCP 2.6, RCP 4.5 and RCP 8.5 scenarios are lies between 80.1% and 99.4% for both maximum and minimum temperature and 50 to 90% for precipitation. During validation, R^2 value for both monthly seasonal sub-model followed by bias correction was between 76.9% and 99.2% for both maximum and minimum temperature, and 55% to 95.2% for precipitation. A detailed modelling approach is incorporated to Hanwella sub-watershed (1799.67 km2) of the Kelani River basin, to study the subsequent water resource management options with the varying streamflow of the Kelani River basin under the effect of the future (2020's, 2050's and 2080's) rainfall and temperature as impending climate change impacts for RCP scenarios. The paper reviews the current state of the catchment as well as the suitability of applying the GCM's rather than RCM's to Sri Lanka to assess this river basin, according to monthly, seasonal and annual variations of the climatology. Apart from the water resources management, a quantitative analysis was conduct to assess the change in the amount of surface water within the selected river basin as a function of the expected variations in precipitation and temperature. This study will set the baseline for commencing and continuing quantitative studies incorporating the behaviour of the basin-wide climatology and streamflow variability with the use of general circulation models

Key words: - Climate Change, GCM, RCP Scenarios, Statistical Downscaling, Water Resources Management

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Networks
AR4	-	Assessment Report 04
AVGPRCP	-	Annual Average Precipitation
BC	-	Bias Correction
CanESM2	-	Canadian Earth System Model Version 02
CCCMA	-	Canadian Centre for Climate Modelling and Analysis
CDD	-	Consecutive Dry Days (Maximum number of consecutive days with rainfall < 1 mm)
CE	-	Coefficient of Efficiency
CGCM3	-	Coupled Global Climate Change Model Version 03
CMIP	-	Coupled Model Intercomparison Project
CORDEX	-	Coordinated Regional Climate Downscaling Experiment
CWD	-	Consecutive Wet Days (Maximum number of consecutive days with rainfall > 1 mm)
DS	-	Dual Simplex
DTR	-	Diurnal Temperature Range (Annual mean difference between TX and TN)
E	-	Explained Variance
ENSO	-	El Nino Southern Oscillation
ETR	-	Extreme Temperature Range (Annual difference between highest TX and lowest TN)
GCM	-	General Circulation Model
HadCM3	-	Hadley Centre Climate Model version 03
HEC-HMS	-	Hydrologic Engineering Centre - Hydrologic Modeling System
IDW	-	Inverse Distance Weightage Method
IPCC	-	Inter-governmental Panel for Climate Change
MCL	-	Maximum Conservation Level
MCM	-	Million Cubic Meters
MRAE	-	Mean Ratio of Absolute Error
NAO	-	North Atlantic Oscillations
NASA	-	National Aeronautics and Space Administration
NCEP	-	National Centre for Environmental Predictions
NCEP-M	-	National Centre for Environmental Predictions - Monthly Model
NCEP-S	-	National Centre for Environmental Predictions - Seasonal Model
NCER	-	National Centre for Environmental Research
OLS	-	Ordinary Least Squares
P_{CONT}	-	Control Period Temperature
P_{deb}	-	De-biased Precipitation
PEP	-	Percent Error in Peak
PEV	-	Percentage Error Volume
P_{obs}	-	Observed Precipitation
PRCPTOT	-	Annual Total Wet Say Precipitation
PRP	-	Percentage Reduction of Partial Correlation
P_{SCEN}	-	Scenario Period Precipitation
R10	-	Number of Heavy Precipitation Days (Daily Rainfall ≥ 10 mm)
R^2	-	Goodness of Fit
R20	-	Number of Very Heavy Precipitation Days (Daily Rainfall ≥ 20 mm)
R95p	-	Very Wet Days (Annual Total PRCP when daily rainfall > 95^{th} percentile)
R99p	-	Extremely Wet Days (Annual Total PRCP when daily rainfall > 99^{th} percentile)

RAEM	-	Ratio of Absolute Error to Mean Error
RCM	-	Regional Climate Model
RCP	-	Representative Concentration Pathways
RE_μ	-	Relative Error of Mean
RE_σ	-	Relative Error of Standard Deviation
RMSE	-	Root Mean Square Error
RR	-	Rainfall Record
RX-1day	-	Maximum 1-day precipitation (Annual maximum 1-day precipitation)
RX-5day	-	Maximum 5-day precipitation (Annual maximum consecutive 5-day precipitation)
SAR	-	Sum of Absolute Residuals
SDSM-M	-	Statistical Downscaling Model - Monthly Model
SDSM-S	-	Statistical Downscaling Model - Seasonal Model
SE	-	Standard Error
SRES	-	Special Report on Emission Scenarios
SSR	-	Sum of Squared Residuals
SU25	-	Summer Days (Annual count when daily maximum temperature > 25°C)
T_{CONT}	-	Control Period Temperature
T_{deb}	-	De-biased Temperature
T_{max}	-	Maximum Temperature
T_{min}	-	Minimum Temperature
TN10p	-	Cool Nights (Percentage of days when Temperature Minimum < 10^{th} percentile)
TN90p	-	Warm Nights (Percentage of days when Temperature Minimum > 90^{th} percentile)
TN_n	-	Minimum of Temperature Minimum (Annual minimum value of daily minimum temperature)
TN_x	-	Maximum of Temperature Minimum (Annual maximum value of daily minimum temperature)
T_{obs}	-	Observed Temperature
TR20	-	Tropical Nights (Annual count when daily minimum temperature > 20°C)
T_{SCEN}	-	Scenario Period Temperature
TX10p	-	Cool Days (Percentage of days when Temperature Maximum < 10^{th} percentile)
TX90p	-	Warm Days (Percentage of days when Temperature Maximum > 90^{th} percentile)
TX_n	-	Minimum of Temperature Maximum (Annual minimum value of daily maximum temperature)
TX_x	-	Maximum of Temperature Maximum (Annual maximum value of daily maximum temperature)
UNEP	-	United Nations Environment Program
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UNFCCC	-	United Nations Framework Convention on Climate Change
WMO	-	World Meteorological Organization
μ	-	Mean
σ	-	Standard Deviation

LIST OF FIGURES

LIST OF TABLES