POTENTIAL SHIFTING OF CLIMATE ZONES AND ASSOCIATED HYDROLOGICAL IMPACTS UNDER CHANGING CLIMATE CONDITIONS IN 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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The above candidate has carried out research for the Master's thesis under my supervision.

Name of the Supervisor: Dr. H.G.L.N. Gunawardhana

Signature of the Supervisor: Date: 2024-02-14

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Potential Shifting of Climate Zones and Associated Hydrological Impacts under Changing Climate Conditions in Sri Lanka

ABSTRACT

Climate change plays a significant role in decision-making related to water resources management. Understanding the future climate of Sri Lanka is crucial for the development of adaptation and mitigation strategies. This study investigated the potential shifting of climate zones in Sri Lanka under changing climate conditions using the Köppen-Geiger Climate Classification system and identified the associated hydrological impacts. The research utilized observed daily precipitation data from 27 meteorological stations. Predictive mean matching (PMM) and normal imputation method (Norm) were employed using the Multiple Imputation by Chained Equations (MICE) algorithm to impute missing data. The performances of 15 Global Climate Models (GCMs) from Coupled Model Intercomparison Project Phase 6 (CMIP6) were evaluated using the Evaluation Based on Distance from Average Solution (EDAS) method. In distributing station data into higher spatial resolution, a linear regression analysis was conducted to develop a relationship between observed station data points with corresponding Climate Hazards Group InfraRed Precipitation with Station data (CHIRPs) grid cells. The calculated gradient values (m) were then utilized to distribute historical and future projection data from GCMs to each CHIRPs cell (0.05˚ resolution). Furthermore, a distributed hydrological model was used with a 0.05˚×0.05˚ grid cell resolution for calculating water balance and identifying hydrological impacts of future climate change on basin hydrology.

The results depicted varied performance among the CMIP6 models in simulating the monsoon climate of Sri Lanka. The MPI-ESM1-2-HR, CNRM-CM6-1-HR, and CNRM-ESM2-1 models were identified as the top performers in simulating monsoon rainfall patterns in both the wet and intermediate zones, while the CNRM-ESM2-1, CNRM-CM6-1-HR and MRI-ESM2-0 models emerged as the top GCMs for the dry zone. The CNRM-CM6-1-HR and CNRM-ESM2-1 models were the best-performing models among the selected GCMs, with the high-resolution version of CNRM-CM6-1-HR being well-suited for small countries like Sri Lanka. When the Mean-Based method and the Quantile Mapping (QM) method were compared for bias correction performances, the QM method demonstrated strong relationships between observed data and model projections. The results of the Köppen-Geiger Climate Classification indicated that future climate zone influenced by climate change, particularly in the South-West region and the highland areas of Sri Lanka. Highland climates will be the most affected in all projection scenarios, with Cfb and Cwb climate zones projected to disappear under the SSP5-8.5 long-term (TL, 2070-2100) scenario. The outcomes of these changes in basin level indicated that, in the near-term (TN, 2020-2050) period, basins in the eastern side of the island will experience decreased runoff while the west will show an increase. Analyzing the Wet zone under SSP1-2.6 showed a 10% TN increase in runoff, rising to 15% in TL. Under SSP5-8.5, the runoff increase is more significant at 27% (TN) and 38% (TL) levels. In the Dry zone under SSP1-2.6, the TN projections result a 10% increase in runoff, escalating to 35% in the TL period. The findings of this study highlight that the potential climate shifts associated with global warming scenarios vary across distinct regional climate zones in Sri Lanka. This underscores the necessity for region-specific adaptation strategies to effectively mitigate the multifaceted impacts on water resources.

Keywords: Climate Change, Data Imputation, Distributed Hydrological Model, Köppen-Geiger Climate Classification

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List of Abbreviations

ACCESS	- Australian Community Climate and Earth-System Simulator
Af	- Tropical Rainforest Climate
AIM/CGE	- Asia-Pacific Integrated Model with Computable General Equilibrium
Am	- Tropical Monsoon Climate
AMIP	- Atmospheric Model Inter-comparison Project
ARCCSS	- Australian Research Council Centre of Excellence for Climate System Science
ASTER GDEM	- Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model
Aw	- Tropical Savanna
BCC	- Beijing Climate Center
CAMS	- Chinese Academy of Meteorological Sciences
CAS	- Chinese Academy of Sciences
CDF	- Empirical CumulativeDensity Function
CERFACS	- Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (European Centre for Research and Advanced Training in Scientific Computation)
CESM	- Community Earth System Model
Cfb	- Subtropical Highland Climate without a Dry Season
CHIRPs	- Climate Hazards Group InfraRed Precipitation with Station
CMA	- China Meteorological Administration
CMCC	- Centro Euro-Mediterraneo sui Cambiamenti Climatici (Euro-Mediterranean Center on Climate Change)
CMIP	- Coupled Model Intercomparison Project
CNRM	- Centre National de Recherches Météorologiques (National Center for Meteorological Research)
Csb	- Warm-Wummer Mediterranean Climate
CSIRO	- Commonwealth Scientific and Industrial Research Organisation

Cwb	- Subtropical Highland Climate with a Dry Season
DEM	- Digital Elevation Model
ECDF	- Empirical Cumulative Distribution Function
EDAS	- Evaluation Based on Distance from Average Solution
ERA	- European Reanalysis
ESGF	- Earth System Grid Federation
ESM	- Earth System Model
ET	- Evaporation
FGOALS	- Flexible Global Ocean-Atmosphere-Land System
FIM	- First Inter Monsoon
GCM	- Global Climate Model
GFDL	- Geophysical Fluid Dynamics Laboratory
GHG	- Green Hosue Gas
GLOBIOM	- Global Biosphere Management Model
GPCC	- Global Precipitation Climatology Centre
GPCP	- Global Precipitation Climatology Project
HR	- High Resolution
IIASA	- International Institute for Applied Systems Analysis
INM	- Institute of Numerical Mathematics
IPCC	- Intergovernmental Panel on Climate Change
MAE	- Mean Absolute Error
MAgPIE	- Model of Agricultural Production and its Impact on the Environment
MAP	- Mean Annual Precipitation
MAT	- Mean Annual Temperature
MESSAGE	- Model for Energy Supply Strategy Alternatives and their General Environmental Impacts
MICE	- Multiple Imputation by Chained Equations
MPI-M	- Max Planck Institute for Meteorology

MRI	- Meteorological Research Institute
NCAR	- National Center for Atmospheric Research
NDA	- Negative Distance from the Average Solution
NEM	- North East Monsoon
NIES	- National Institute for Environmental Studies
NOAA	- National Oceanic and Atmospheric Administration
Norm	- Normal Imputation Method
NRMC	- Natural Resources Management Centre
PBIAS	- Percentage Bias
PBL	- Planetary Boundary Layer
PDA	- Positive Distance from the Average Solution
P_{dry}	- precipitation of the driest month
PERSIANN	- Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks
PMM	- Predictive Mean Matching Method
P_{sdry}	- precipitation of the driest month in summer
P_{swet}	- precipitation of the wettest month in summer
P_{wdry}	- precipitation of the driest month
P_{wwet}	- precipitation of the wettest month in winter
QM	- Quantile Mapping
R	- Correlation Coefficient
RCM	- Regional Climate Model
RCP	- Representative Concentration Pathways
REMIND	- Regionalized Model of Investments and Development
RMSE	- Root Mean Square Error
RRI	- Rainfall-Runoff-Inundation
SIC	- Sea Ice Concentrations
SIM	- Second Inter Monsoon
SS	- Taylors Skill Score

SSP	- Shared Socioeconomic Pathways
SST	- Sea Surface Temperatures
SWAT	- Soil and Water Assessment Tool
SWM	- South West Monsoon
TB	- Historical Period
T_{cold}	- Temperature of the Coldest Month
T_{hot}	- Temperature of the Hottest Month
TL	- Long-Term Period
T_{mon10}	- Number of Months Where the Temperature is Above 10
TN	- Near Term Period
TRMM	- Tropical Rainfall Measuring Mission
WaPOR	- Water Productivity Open-access portal
WMO	- World Meteorological Organization
μ	- Mean
σ	- Standard Deviation