ASSESSING WATER- USE EFFICIENCY IN THE AGRICULTURAL SECTOR IN THE MALWATHU OYA RIVER BASIN UNDER CHANGING CLIMATE SCENARIOS

Suraweerage Buddhi Prasad

228093U

Degree of Master of Science

Department of Civil Engineering

Faculty of Engineering

University of Moratuwa

Sri Lanka

August 2024

ASSESSING WATER- USE EFFICIENCY IN THE AGRICULTURAL SECTOR IN THE MALWATHU OYA RIVER BASIN UNDER CHANGING CLIMATE SCENARIOS

Suraweerage Buddhi Prasad

228093U

Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree

Master of Science

Department of Civil Engineering

Faculty of Engineering

University of Moratuwa

Sri Lanka

August 2024

DECLARATION

I declare that this is my work, and this thesis/dissertation 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 acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: UOM Verified Signature Date: 30/08/2024

The above candidate has carried out research for the ~~PhD/MPhil~~/Masters thesis/~~dissertation~~ under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. P. K. C. De Silva

Signature of the Supervisor: UOM Verified Signature Date: 30/08/2024

ACKNOWLEDGEMENT

The Author would like to express his sincere gratitude to Dr P.K.C. De Silva, Dr H.G.L.N. Gunawardhana, Prof. RLHL Rajapakse and Dr L. Muthuwatta for their valuable supervision and guidance. The author wishes to convey his gratitude to all the academic staff of the Civil Engineering Department, including the Head of the Department, Prof. Mrs C. Jayasinghe and the Research Coordinator, Dr T.M.N. Wijayaratna, for their support throughout this period.

Further, the author would like to thank the Department of Meteorology and Irrigation Department of Sri Lanka for providing the necessary data. The author wishes to acknowledge and offer gratitude to the Department of Civil Engineering, University of Moratuwa, and Faculty of Graduate Studies of the University of Moratuwa for the assistance provided for the research study. In conclusion, the author wishes to thank the UNESCO Madanjeet Singh Centre for South Asia Water Management (UMCSAWM) for providing the required facilities and funding for this research study.

ABSTRACT

ASSESSING WATER- USE EFFICIENCY IN THE AGRICULTURAL SECTOR IN THE MALWATHU OYA RIVER BASIN UNDER CHANGING CLIMATE SCENARIOS

Climate change, conventional agricultural techniques and malfunctioning irrigation systems pose significant challenges to efficient water management in the dry zone of Sri Lanka. Agricultural activities in the dry zone mainly depend upon irrigation reservoirs attached to the hydrodynamics of dry zone basins. Assessing the water use efficiency (WUE) of an irrigation scheme in a water-scarce region is paramount for developing a robust water management strategy considering the escalating impacts of climate change.

Nachchaduwa Irrigation Scheme, situated in the Malwathu Oya basin, Sri Lanka, constitutes the required characteristics of a dry zone irrigation system for this research study about climate change impacts on irrigation supply efficiency. The developed methodology includes two primary components: crop water requirement estimation and irrigation supply estimation. The analysis of crop water requirement estimates revealed distinct seasonal variations. During the Maha season, the crop water demand decreased due to increased rainfall events, with the estimated mean crop water requirement dropping from 1,166.87 mm/season in the base period to 1,076.15 mm/season under SSP 1-2.6 and 1,053.17 mm/season under SSP 5-8.5. Conversely, the Yala season experienced higher water demand under the SSP 5-8.5 scenario with 774.41 mm/season, where the base period requirement is 767.18 mm/season, indicating a 0.9% rise.

The HEC-HMS model has been used to simulate river inflow to the Nachchaduwa Reservoir prior to obtaining the irrigation supply through reservoir operation simulations. Results indicated significant variability in future water availability in the upstream catchment, with a projected mean annual inflow decrease of 8.14% under the SSP 5-8.5 scenario and an increase of 43.16% under the SSP 1-2.6 scenario. The increased variability in inflow highlighted the potential for frequent and severe extreme rainfall events under considered climate scenarios. The two-point hedging rule theory was adopted in reservoir operation simulations for irrigation supply estimation. The annual mean irrigation supply during the base period ranged from 866.56 mm/season to 1,148 mm/season, which shows a decline under the SSP 1-2.6 scenario but increases the variability under the SSP 5-8.5 scenario. These findings manifest the need for resilient irrigation management practices to address future climatic challenges in dry zone irrigation schemes in Sri Lanka.

Keywords: Crop water requirement, HEC-HMS, Irrigation supply, Nachchaduwa Reservoir

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
AMIP	Atmospheric Model Intercomparison Project
CMIP	Coupled Model Intercomparison Project
DEM	Digital Elevation Model
GCM	Global Circulation Model
GMIS	Global Man-Made Impervious Surface
HEC-HMS	Hydrologic Engineering Center's Hydrologic Modeling System
HEC-ResSIM	Hydrologic Engineering Center's Reservoir Simulation
HEIFLOW	Hydrological-Ecological Integrated Watershed-Scale Flow
HLMC	High-Level Main Canal
HydroSHEDS	Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales
IPCC	Intergovernmental Panel on Climate Change
LLMC	Low-Level Main Canal
MCM	Million Cubic Meters
NIWR	Net Irrigation Water Requirement
NRCS	Natural Resources Conservation Service
NSE	Nash Sutcliffe Efficiency
PBIAS	Percentage Bias
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RMSE	Root Mean Square Error
RSR	RMSE-Observations Standard Deviation Ratio
SBUH	Soil-Bio-Water-Urban Hydrology
SCS CN	Soil Conservation Service Curve Number
SMA	Soil Moisture Accounting
SRES	Special Report on Emission Scenarios
SRTM	Shuttle Radar Topography Mission
SSP	Shared Socioeconomic Pathways

SWAT	Soil And Water Assessment Tool
UN FAO	United Nations Food and Agricultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WUE	Water Use Efficiency