ASSESSING THE COMPOUND IMPACTS OF CLIMATE CHANGE AND LAND USE DYNAMICS ON FUTURE GROUNDWATER AVAILABILITY IN DRYLAND AREAS OF SRI LANKA

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Master of Science (Major Component of Research)

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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).

-- 17/06/2025

Herath K.R.H.M.O.N Date

The above candidate has carried out research for the Master's Thesis/Dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

-- 17/06/2025

Dr. H.G.L.N. Gunawardhana Date

DEDICATION

This thesis is dedicated to my loving parents, whose blind love, unwavering encouragement, and countless sacrifices have been the backbone of my life and studies. Their unrelenting belief in me has provided me with the courage and determination to propel my academic and personal goals forward, even in the face of adversity. I am forever grateful to them for their patience, guidance, and virtues that they instilled in me.

I also dedicate this thesis to all those teachers and mentors who have taught, guided, and inspired me along the way, through my formative earliest years of schooling to this present moment. Their love for learning, their dedication to developing curiosity, and their willingness to share their expertise have shaped me for life in my intellectual and personal development. All of them have contributed to developing my mind, work habits, and aspirations.

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ABSTRACT

Climate change and land use and land cover (LULC) change are the primary challenges that disrupt the hydrological cycle, significantly impacting groundwater availability. While numerous studies have examined how these changes affect hydrological processes, a critical gap exists in understanding their combined impact on groundwater availability. This study addresses that gap by assessing the compound impacts of climate change and LULC change on groundwater resources in the Kumbukkan Oya catchment, a dryland area in southeastern Sri Lanka, where such research is currently lacking. The analysis uses hydrometeorological data, groundwater levels, borehole logs, and catchment characteristics such as land use, soil type, and elevation. Climate data were obtained from 1989 to 2011, while the groundwater level data and hydrological data were used from 2022 to 2024, at a mostly daily time step. Groundwater flow was then numerically modeled with MODFLOW, a three-dimensional numerical software for groundwater flow simulations. Projected future climate was obtained from the Coupled Model Intercomparison Project Phase 6 (CMIP6) using the CNRM-CM6-1-HR General Circulation Model (GCM) and downscaled to the local scale using a stochastic Random Forest (RF) machine learning algorithm. These were considered for the baseline period (1989–2011) and the future projection period (2030–2049) under the high-emission SSP5-8.5 scenario. Land use data of 2018 and projected for future conditions were employed in assessing LULC dynamics. The MODFLOW model was calibrated and validated using four monitoring wells. According to the result, the model captures the seasonal patterns of decline and recovery, particularly in the upstream, although some overestimation occurred in mid-catchment areas. Future projections indicate a decrease in seasonal rainfall compared to the baseline period, with reduced average rainfall but still frequent extreme events. The future period total rainfall will be 1,591 mm, which is a reduction of 220 mm from the observed total of 1,811 mm. Based on the projected results, groundwater levels are expected to decline by approximately 0.43 m to 0.65 m compared to observed conditions. Therefore, simulation reveals that the Kumbukkan Oya catchment has some extent of resilience in the groundwater level relative to the projected climate and land use change. However, localized tendencies in the fall in groundwater levels suggest the need for site-specific adaptation responses, particularly over vulnerable recharge zones. The study provides valuable insights to policymakers and water resource planners in developing sustainable groundwater management policy for Sri Lanka's dry regions in the context of future climatic uncertainty.

Keywords: Climatic alterations, Compound Impacts, Land use changes, MODFLOW, Random Forest

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LIST OF ABBREVIATIONS

CMIP	-	Coupled Model Intercomparison Project
CN	-	Curve Number
CORDEX	-	Coordinated Regional Downscaling Experiment
DEM	-	Digital Elevation Model
GCM	-	Global Climate Model
GFZ	-	German Research Centre for Geosciences
GIS	-	Geographic Information System
GRACE	-	Gravity Recovery and Climate Experiment
GWL	-	Ground Water Level
HC	-	Highland Complex
IQR	-	Interquartile Range
LULC	-	Land Use and Land Cover
ML	-	Machine Learning
MODIS	-	Moderate Resolution Imaging Spectroradiometer
NN	-	Neural Network
NWIS	-	National Water Information System
NWSDB	-	National Water Supply and Drainage Board
RCM	-	Regional Climate Model
RF	-	Random Forest
RS	-	Remote Sensing
SAR	-	Synthetic Aperture Radar
SMOS	-	Soil Moisture and Ocean Salinity
SSP	-	Shared Socioeconomic Pathways
SVM	-	Support Vector Machines
USGS	-	United States Geological Survey
VC	-	Vijayan Complex
WRB	-	Water Resources Board

LIST OF APPENDICES