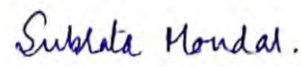


Declaration of the Candidate

I hereby declare that the thesis entitled “IMPACT OF CLIMATE VARIABILITY AND HUMAN ACTIVITIES ON ALTERATION OF RUNOFF IN SOUTH KOEL RIVER BASIN, EASTERN INDIA” submitted by me to the Faculty of Science, University of North Bengal in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Geography and Applied Geography is a bonafide work carried out by me.

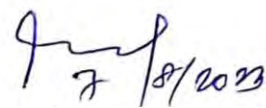
Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature and acknowledgment of collaborative research and discussions. I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degrees or diplomas in this institute or any other institute or University. The work was done under the supervision of Rupak Kumar Paul, Assistant Professor in the Department of Geography & Applied Geography, University of North Bengal.

Date: 07.08.2023


(Subrata Mondal)

In my capacity as supervisor of the candidate's thesis, I certify that the above statements are true to the best of my knowledge.

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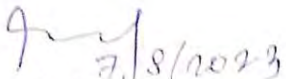
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IMPACT OF CLIMATE VARIABILITY AND HUMAN ACTIVITIES ON ALTERATION OF RUNOFF IN SOUTH KOEL RIVER BASIN, EASTERN INDIA A thesis submitted to the Faculty of Science, University of North Bengal in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Geography and Applied Geography Submitted by Subrata Mondal Registration No. 213020 of 2018-2019 Supervisor Rupak Kumar Paul Assistant Professor Department of Geography and Applied Geography University of North Bengal Raja Rammohunpur, P.O. – NBU District – Darjeeling, PIN – 734013 August, 2023

1 Chapter 1: INTRODUCTION 1.1. Prelude Runoff is the most significant indicator to assess our valuable water resources which are profoundly altered by the simultaneous effect of climate variability and human activities around the globe exerting enormous pressure on freshwater availability and modifying catchment hydrology (Giambelluca, 2005) with potentially significant consequences for water availability, floods and droughts, erosion and sedimentation, ecosystem health, and human well-being, irrespective of its spatial and temporal extents. Two types of alterations or changes can be found in basin runoff: one is the gradual change (also called trend) and another is called step change (also called sudden or abrupt change). However, climate variability (or climate change) and human activities are the two major driving forces that independently cause such runoff alteration at the basin scale, although at the larger scale (e.g., hemispheric or global scale) both the factors are functionally found to be dependent to each other (Wang, Ishidaira, & Xu, 2012; Seyoum, Milewski, & Durham, 2015). Direct human intervention in the basin hydrologic system like water abstraction for domestic water use, irrigation, and agricultural practices, industrialization (Liu et al., 2019) and water diversion (Wang, Wang, Fu, & Zhang, 2016) etc., and ensuing runoff change can be easily discernible and accordingly, the remedial measures can be formulated but indirect human interference that occurs through a change in LULC (Afonso de Oliveira Serrão et al., 2022) very often remains invisible and, that is why, in water resource planning the issue does not get priority and importance. But this LULC change coupled with climate variability cause irreversible change in basin scale hydrologic system and its adverse impact on human society extends far beyond in future generations (Rivas-Tabares, Tarquis, De Miguel, Gobin, & Willaarts, 2022). Although it is a global phenomenon, the issue has regional implications because of much geographical variations in river basin characteristics across the continents, and hence, the runoff response is getting manifested differently around the globe (Vörösmarty, Green, Salisbury, & Lammers, 2000) depending upon the scale of river basin (Xu, Yang, Yang, & Lei, 2014; Anil & Ramesh, 2017; Khoi, Nguyen, Sam, & Nhi, 2019; Pirmia et al., 2019; M. Wang et al., 2020), degree of human interference in the river basin (J. Chen, Li, & Zhang, 2005; Liang et al., 2015; H. Zhang, Meng, Wang, Wang, & Li, 2020; X. Tang et al., 2021), variation of geophysical condition of river basin (Khoi et al., 2019; Ma, Xu, Luo, Prasad Aggarwal, & Li, 2009; Zeng, Zhan, Sun, Du, & Wang, 2015; S. Zhou, Zhang,


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TO WHOM IT MAY CONCERN

This is to certify that Mr. Subrata Mondal, a Ph.D scholar of the Department of Geography & Applied Geography, University of North Bengal, bearing Registration No. Ph.D/Geog.(1716)/682/R-2023, Dated: 16/05/2023, has successfully completed the Ph.D thesis entitled “IMPACT OF CLIMATE VARIABILITY AND HUMAN ACTIVITIES ON ALTERATION OF RUNOFF IN SOUTH KOEL RIVER BASIN, EASTERN INDIA”.

He has carried out this work under my supervision. To the best of my knowledge, this is the original work, and in doing this work, the candidate has fulfilled all necessary requirements stipulated in the M.Phil./Ph.D Regulation 2016 of the University of North Bengal.

Now, the thesis may be submitted for evaluation.

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I would like to pay my humble regards and immense sense of gratitude to my supervisor, Rupak Kumar Paul, Assistant Professor, Department of Geography & Applied Geography, University of North Bengal, for his noble supervision, untiring academic guidance, valuable suggestions, constant encouragements, and critical comments all through the research endeavour. His prudent direction, and all sorts of support, for the preparation of this thesis can never be forgotten.

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August 07, 2023
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Preface

The present study is carried out in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Geography and Applied Geography in the Faculty of Science, University of North Bengal. The whole work is a kind of case study in which an attempt has been made to explore the impact of climate variability and human activities on the alteration of runoff in the South Koel River basin in Eastern India.

The text has been arranged into five chapters. The first chapter presents a general introduction to the study, which includes the research problem, the description of the study area, a literature review, research questions, research objectives, a brief description of the database and methodology, scope, and limitations of the research.

The second chapter deals with the analysis of step change and trend in rainfall and runoff time series pertaining to the South Koel River basin. The methodology and databases were categorically described, and the results have been interpreted with as much clarity as possible. The first objective of current research has been achieved in this chapter.

The third chapter deals with the impact of climate and human activities on runoff which fulfils the second research objective. Here, also methodological design and database have been described with as much clarity as possible. The results have been presented in tabular form and visualized by using relevant graphical techniques. An attempt has been made to interpret the result logically without any biases.

The fourth chapter deals with the sensitivity of runoff to change in three specific land use land cover classes, namely forest, agriculture, and built-up area. Here, an attempt has been made to capture separately the threshold value beyond which the runoff changes significantly. Finally, the fifth chapter mentions the major findings and conclusion.

The references and citations have been made using the American Psychological Association style (APA style), sixth edition, and references have been given at the end part of the thesis. An attempt has been made to follow the American style of spelling. I am responsible for any kind of mistake or error if found in this work.

This study might be helpful to hydrologists, environmental scientists, environmental engineers, ecologists, administrators, and policymakers to know the mechanism of runoff change caused by climate variability and human activity with special reference to the South Koel River basin. The database which has been generated in this investigation may provide valuable input for formulating the required policy and strategic plan in view to overcoming the adverse impact of those changes occurring in the concerned basin.

After getting the certificate from my supervisor and the necessary plagiarism clearance from the concerned authority, the thesis is submitted for its evaluation.

August 07, 2023

Raja Rammohumpur

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List of Acronyms and Abbreviations

ANN	:	Artificial Neural Network
C	:	Centigrade
CWC	:	Central Water Commission
cumec	:	Cubic meter per second
DEM	:	Digital Elevation Model
GSI	:	Geological Survey of India
GLUE	:	Generalized Likelihood Uncertainty Estimation
HYV	:	High Yielding Variety
IMD	:	India Meteorological Department
km	:	Kilometer
km ²	:	Square Kilometer
LULC	:	Land use and land cover
m	:	Meter
MCM	:	Million Cubic Meter
MCMC	:	Markov Chain Monte Carlo
mm	:	Millimeter
n	:	Number
NASA	:	National Aeronautics and Space Administrations
NSE	:	Nash Sutcliff Efficiency
OLI	:	Operational Land Imager
ParaSol	:	Parameter Solution
PSO	:	Particle Swarm Optimization
PTF	:	Pedo-transfer Function
SCS-CN	:	Soil Conservation Services Curve Number
SPSS	:	Statistical Package for Social Sciences
SRTM	:	Shuttle Radar Topographic Mission
SUFI-2	:	Sequential Uncertainty Fitting Version 2
SWAT	:	Soil and Water Assessment Tool
TM	:	Thematic Mapper
USGS	:	United States Geological Survey
WGS84	:	World Geodetic System 1984
yr	:	Year