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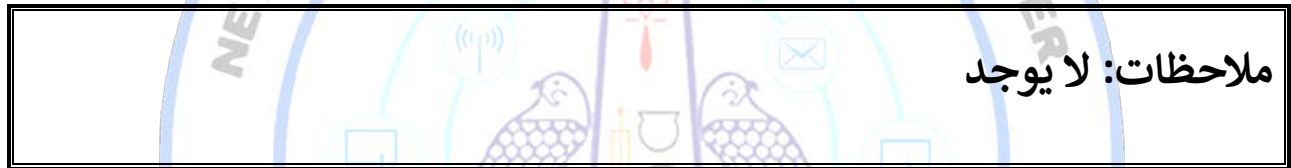
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Cairo University

A NEW COMPOSITE INDEX FOR IDENTIFYING DROUGHT EVENTS: A CASE STUDY OF THE BLUE NILE RIVER BASIN

By

Marwa Ali Sayed Ali

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Irrigation and Hydraulics Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2022

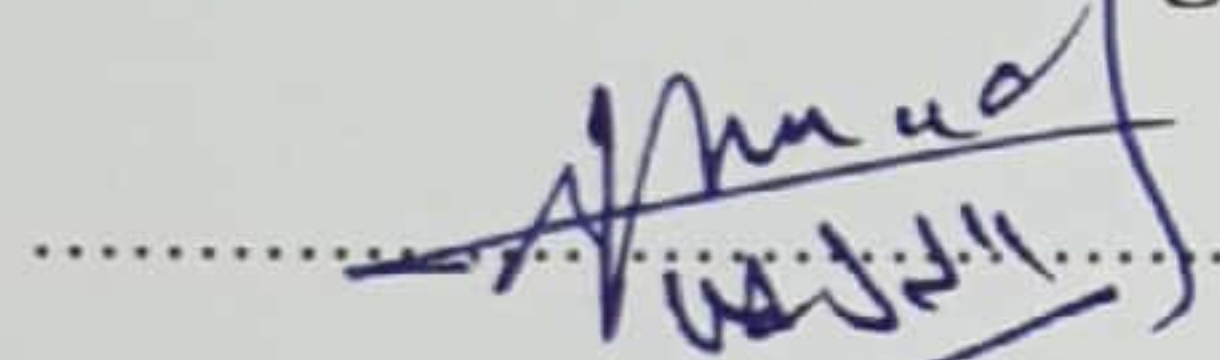
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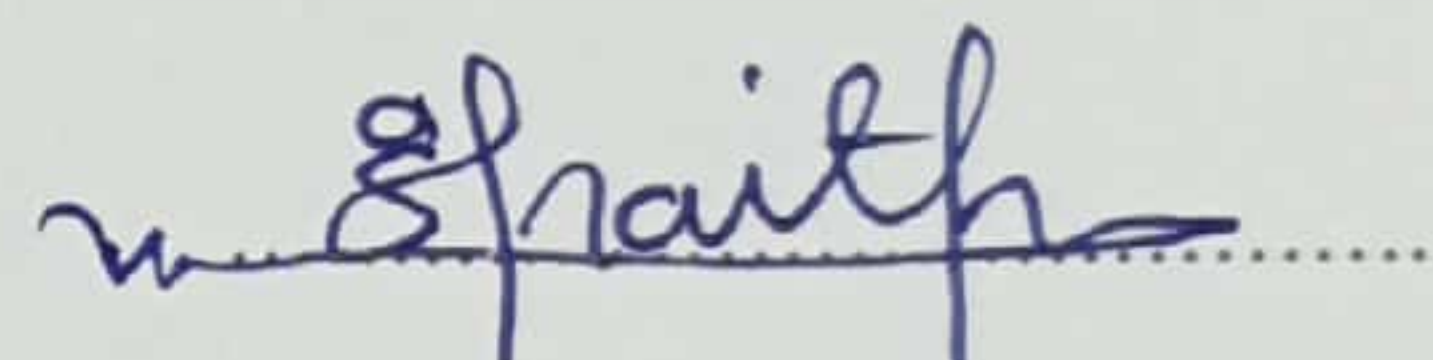
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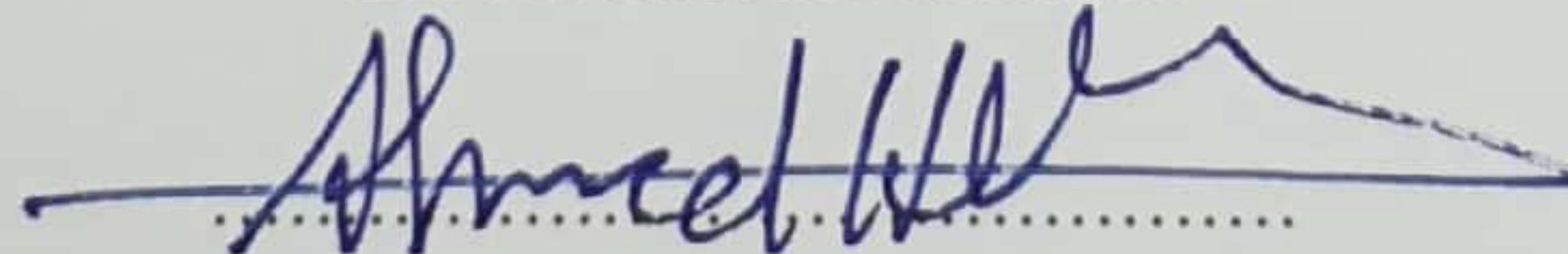
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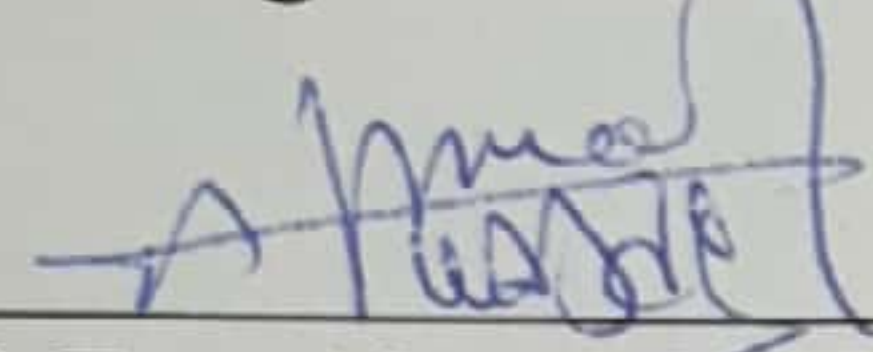
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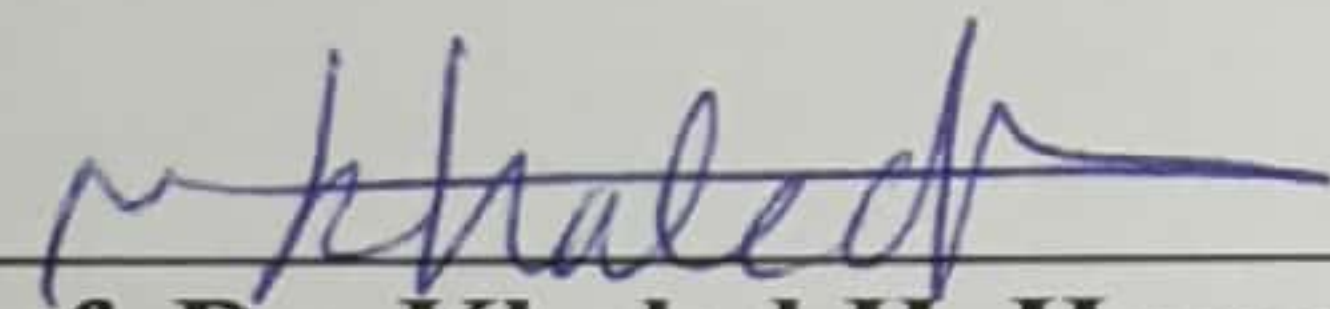
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Title of Thesis:

A New Composite Index for Identifying Drought Events: A Case Study of the Blue Nile River Basin

Key Words:

Composite Drought Index (CDI); Drought Indices; Blue Nile; Principal Component Analysis (PCA); Drought Monitoring

Summary:

Drought is a slow-onset phenomenon that evolves over a season or even years. Drought affects people more than any other natural disaster due to its widespread and significant negative impacts. Population growth and associated water demand add further stress to water resources, especially in periods of drought. Drought indices represent a single value resulting from processing a considerable amount of data. These indices provide a short message to stakeholders to adapt water resource management strategies. Since drought results from interconnected phenomena, designing a composite drought index that includes several drought indices can accurately capture drought events. Drought assessment over a large-scale basin (e.g., the Blue Nile) is a challenging objective that has not been deeply tackled before except for small portions of the basin. This research assessed droughts over the whole basin by evaluating meteorological, agricultural, and hydrological drought indices. The calculated drought indices (Standardized Runoff Index (SRI), Standardized Precipitation Index (SPI), and Standardized Soil Moisture Index (SSI)) in addition to the development of a new standardized evapotranspiration index (sETI) are jointly integrated into a novel composite drought index for the Blue Nile (BNI). The optimal weights for SPI, SRI, sETI, and SSI were 0.33, 0.26, 0.19, and 0.22, respectively, in the designed BNI.

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Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Marwa Ali Sayed Ali

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Signature:

Dedication

I dedicate this work to the memory of my beloved brother Mohammed Ali, who is no longer with us and has left a void in our lives that will never be filled. Despite the fact that your life was brief, I will ensure that your memory goes on for as long as I live. I love you and miss you beyond words. May Allah (SWT) grant you Jannah Firdaws. Amen.

Acknowledgments

الحمد لله الذي بنعمته تتم الصالحات، وبفضله تنزل الخيرات والبركات وبتوفيقه تتحقق المقاصد والغايات

Firstly, I would like to express my endless gratitude to my research supervisors Prof. Dr. Ahmed Wagdy, Dr. Mostafa Ghaith, and Dr. Ahmed Helmi for their support, guidance, and their patience until this work formed a complete piece.

Gratitude is extended to Dr. Doaa Amin, the head of Nile Basin studies department at Water Resources Research Institute, who supported me in every way she can.

My sincerest thanks and debt are owed to my family who are the real catalyst through this tough journey.

Special thanks to all my friends, colleagues, and acquaintances who provided me with emotional care and professional advices. If I mention everyone by name, I will need to fill volumes. It was a long path and you never gave up on believing in me.

Table of Contents

DISCLAIMER	I
DEDICATION	II
ACKNOWLEDGMENTS	III
TABLE OF CONTENTS	IV
LIST OF TABLES	VI
LIST OF FIGURES	VII
NOMENCLATURE	IX
ABSTRACT	X
CHAPTER 1 : INTRODUCTION	1
1.1. BACKGROUND.....	1
1.2. PROBLEM DESCRIPTION	2
1.3. OBJECTIVES	3
1.4. RESEARCH INNOVATION	3
1.5. ORGANIZATION OF THE THESIS.....	3
CHAPTER 2 : LITERATURE REVIEW AND STUDY AREA	4
2.1. BACKGROUND.....	4
2.2. DROUGHT, WATER SCARCITY AND ARIDITY.....	6
2.3. DROUGHT CHARACTERISTICS	7
2.4. DROUGHT INDICES	8
2.5. DROUGHT ANALYSIS	11
2.6. DROUGHT ASSESSMENT IN THE BLUE NILE BASIN.....	12
2.7. STUDY AREA.....	16
CHAPTER 3 : DATA AND METHODOLOGY	18
3.1. DATA	18
3.1.1. Precipitation (P)	18
3.1.2. Streamflow (Q)	19
3.1.3. Evapotranspiration (ET).....	19
3.1.4. Soil Moisture (SM)	21
3.1.5. Data characteristics, Quality, and Homogeneity Test	22
3.2. METHODOLOGY	25
3.2.1. Standardized Indices	25
3.2.1.1 Standard Precipitation Index (SPI).....	25
3.2.1.2. Standardized Evapotranspiration Drought Index (sETI)	30
3.2.1.3. Standardized Soil Moisture Drought Index (SSI).....	30
3.2.1.4. Surface Runoff Index (SRI)	30
3.2.2. Principal Component Analysis (PCA)	31
3.2.3. De-Seasonalizing of the input indices	33

3.2.4.	Developing the Composite Drought Index	34
3.2.5.	Categorizing the Composite Drought Index	34
CHAPTER 4 :RESULTS.....		36
4.1.	METEOROLOGICAL DROUGHT ANALYSIS.....	36
4.1.1.	Temporal Monthly Analysis	36
4.1.2.	Seasonal Analysis	43
4.1.2.1.	Kiremt Time.....	43
4.1.2.2.	Belg Time	46
4.1.3.	Annual Climatic Year	46
4.2.	AGRICULTURAL DROUGHT ANALYSIS	53
4.3.	HYDROLOGICAL DROUGHT ANALYSIS	58
4.4.	HISTORICAL DROUGHT CHARACTERISTICS	68
4.5.	CORRELATION BETWEEN DROUGHT INDICES.....	71
4.6.	COMPOSITE DROUGHT INDEX	76
4.6.1.	De-Seasonalizing the Data	76
4.6.2.	Principal Component Analysis (PCA) Approach	78
4.6.3.	Empirical weight approach	78
4.7.	EVALUATION OF THE BNI.....	79
4.7.1.	Monthly correlation.....	79
4.7.2.	Time scale comparison.....	79
4.8.	SHORT –TERM FORECAST OF THE BNI.....	82
CHAPTER 5 : DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS		83
5.1.	DISCUSSION, AND CONCLUSIONS	83
5.2.	RECOMMENDATIONS FOR FURTHER RESEARCH	85
REFERENCES.....		86
APPENDIX A: DROUGHT INDICES AT DIFFERENT TIMESCALES.....		95

List of Tables

Table 1: An overview of the most commonly used drought indices	10
Table 2: List of the historical drought episodes and their start and end dates during (1969 – 2020) in the Blue Nile Basin	12
Table 3: Statistical characteristics of all variable for available data over the UBN Basin	23
Table 4: Statistical characteristics of all variable for available data over the BN Basin	24
Table 5: The classifications of the SPI	26
Table 6: Specific-duration standardized precipitation indices (SPI) and their applications (NDMC, 2008)	29
Table 7: Characteristics of the historical droughts as identified by the SPI for the UBN	69
Table 8: Characteristics of the historical droughts as identified by the SPI for the BN	69
Table 9: Characteristics of the historical droughts as identified by the SRI at El Diem station	69
Table 10: Characteristics of the historical droughts as identified by the SRI at Khartoum station	70
Table 11: Characteristics of the historical droughts as identified by the SRI at Dongola station	70
Table 12: The Pearson's correlation coefficient (r) matrix at different timescales of the drought indices for the UBN station	72
Table 13: The Pearson's correlation coefficient (r) matrix at different timescales of the drought indices for the BN station	73
Table 14: The correlation between the monthly BNI from PCA and the empirical weight and the monthly SPI, SRI, sETI and SSI from El Diem and the SRI from Dongola	79

List of Figures

Figure 1*: Drought types and the succession of their occurrence.....	6
Figure 2: Natural and man-made water scarcity.....	7
Figure 3: Relationship between drought characteristics.....	8
Figure 4: A) The Nile basin with its major sub-basins its countries; B) The Blue Nile basin and the main flow stations and, C) the topography of the Blue Nile Basin.....	17
Figure 5: Spatial distribution of CHRIPS monthly precipitation over Blue Nile basin (a) in August 2002, (b) in August 2017	19
Figure 6: Evapotranspiration data from GLDAS-Noah V2 product for the Blue Nile, (a) August 2002; (b) August 2017	20
Figure 7: Soil moisture data from GLDAS-Noah V2 product for the Blue Nile, (a) August 2002; (b) August 2017	21
Figure 8: The temporal length of each variable and the BN combined index.....	22
Figure 9: Standard normal distribution with the SPI.....	29
Figure 10: Methodology flowchart for creating the composite drought index	35
Figure 11: Monthly SPI (SPI-1) for the UBN	37
Figure 12: Monthly SPI (SPI-1) for the BN	38
Figure 13: Nine-month SPI (SPI-9) for the UBN.....	39
Figure 14: Nine-month SPI (SPI-9) for the BN.....	40
Figure 15: The 12 months SPI (SPI-12) for the UBN	41
Figure 16: The 12 months SPI (SPI-12) for the BN.....	42
Figure 17: Seasonal SPI for Kerimt season for the UBN	44
Figure 18: Seasonal SPI for Kerimt season for the BN.....	45
Figure 19: Seasonal SPI for Belg the UBN	47
Figure 20: Seasonal SPI for Belg the BN	48
Figure 21: Annual Climatic SPI for the UBN	49
Figure 22: Annual Climatic SPI for the BN	50
Figure 23: The seasonal SPI during Kiremt and Belg, and the annual SPI over the UBN	51
Figure 24: The seasonal SPI during Kiremt and Belg, and the annual SPI over the BN52	
Figure 25: Monthly time steps SPI-1, SSI-1, and sETI-1 over the UBN	54
Figure 26: Monthly time steps SPI-1, SSI-1, and sETI-1 over the BN	55
Figure 27: Three-month time steps SPI-3, SSI-3, and sETI-3 over the UBN	56
Figure 28: Three-month time steps SPI-3, SSI-3, and sETI-3 over the BN.....	57
Figure 29: Monthly SRI (SRI -1) for El-Diem station	59
Figure 30: Monthly SRI (SRI -1) for Khartoum station.....	60
Figure 31: Monthly SRI (SRI -1) for Dongola station	61
Figure 32: Temporal SRI -12 for El-Diem station	62
Figure 33: Temporal SRI -12 for Khartoum station.....	63
Figure 34: Temporal SRI -12 for Dongola station	64
Figure 35: Temporal annual SRI hydrologic year for EL Diem station.....	65
Figure 36: Temporal annual SRI hydrologic year for Khartoum station	66
Figure 37: Temporal annual SRI hydrologic year for Dongola station.....	67
Figure 38: Correlation results among indices for (a) 1- month, (b) 3 month, (c) 6-month, and (d) 9-month accumulation period with a time lag up to 3 months for the UBN.....	74

Figure 39: Correlation results among indices for (a) 1- month, (b) 3 month, (c) 6-month, and (d) 9-month accumulation period with a time lag up to 3 months for the BN	75
Figure 40: The structure of the seasonal cycle of the SPI and after deseasonalizing SPIIn	76
Figure 42: The structure of the seasonal cycle of the sETI and after deseasonalizing sETIn	77
Figure 43: The structure of the seasonal cycle of the SSI and after deseasonalizing SSIn	77
Figure 44: 3-month BNIs with 3-month SRI at ELDiem and 3-month SRI at Dongola	80
Figure 45: 6-month BNIs with 6-month SRI at ELDiem and 6-month SRI at Dongola.	80
Figure A. 1: Three-month SPI (SPI-3) for the UBN	95
Figure A. 2: Six-month SPI (SPI-6) for the UBN	96
Figure A. 3: Three-month SPI (SPI-3) for the BN	97
Figure A. 4: Six-month SPI (SPI-6) for the BN	98
Figure A. 5: Monthly sETI (sETI-1) for the UBN	99
Figure A. 6: Three-month sETI (sETI-3) for the UBN	100
Figure A. 7: Six-month sETI (sETI-6) for the UBN	101
Figure A. 8: Nine-month sETI (sETI-9) for the UBN.....	102
Figure A. 9: 12-month sETI (sETI-12) for the UBN.....	103
Figure A. 10: Monthly sETI (sETI-1) for the BN	104
Figure A. 11: Three-month sETI (sETI-3) for the BN	105
Figure A. 12: Six-month sETI (sETI-6) for the BN	106
Figure A. 13: Nine-month sETI (sETI-9) for the BN.....	107
Figure A. 14: 12-month sETI (sETI-12) for the BN	108
Figure A. 15: Monthly SSI (SSI-1) for the UBN	109
Figure A. 16: Three-month SSI (SSI-3) for the UBN	110
Figure A. 17: Six-month SSI (SSI-6) for the UBN	111
Figure A. 18: Nine-month SSI (SSI-9) for the UBN.....	112
Figure A. 19: 12-month SSI (SSI-12) for the UBN.....	113
Figure A. 20: Monthly SSI (SSI-1) for the BN	114
Figure A. 21: Three-month SSI (SSI-3) for the BN	115
Figure A. 22: Six-month SSI (SSI-6) for the BN	116
Figure A. 23: Nine-month SSI (SSI-9) for the BN.....	117
Figure A. 24: 12-month SSI (SSI-12) for the BN	118

Nomenclature

asl	above sea level
BN	Blue Nile
BNi	Blue Nile Drought Index
CDI	Composite Drought Index
CHC	Climate Hazards Center
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CMIP5	Coupled Model Intercomparison Project Phase 5
CRU	Climatic Research Unit
D	Drought Duration
EM - DAT	Emergency Events Database
ENB	Eastern Nile Basin
GAR	Global Assessment Report on Disaster Risk Reduction
GLDAS	Global Land Data Assimilation System
GCM	Global Climate Models
I	Drought Intensity
LBN	Lower Blue Nile
LSMs	Land Surface Models
M	Drought Magnitude
MAP	Mean Areal Precipitation
NB	Nile River Basin
NDMC	National Drought Mitigation Center
PCA	Principal Component Analysis
PET	Potential Evapotranspiration
RCPs	Representative Concentration Pathways
RMSE	Root Mean Square Error
RS	Remote Sensing
S	Drought Severity
sETI	Standardized Evapotranspiration Drought Index
SM	Soil Moisture
SMrz	Soil Moisture in the root zone
SDGs	Sustainable Development Goals
SPI	Standardized Precipitation Index
SRI	Surface Runoff Index
SSI	Standardized Soil Moisture Drought Index
UBN	Upper Blue Nile
USGS	U.S. Geological Survey
WCRP	World Climate Research Project
WMO	World Meteorological Organization
WRF	Weather and Forecasting model

Abstract

Drought is a normal part of climate just like floods, and hurricanes. Although floods and hurricanes have a beginning, and end, drought is a slow-onset phenomenon that evolves over a season or even years. Drought affects people more than any other form of a natural disaster, due to its widespread and significant impacts on the environment, and the communities.

Egypt is the most sensitive country to any change within the Blue Nile (BN) system. The population growth and associated water demand will add high pressure in periods of droughts and will generate a long-term environmental, economic, and health impact on the population. Therefore, efforts should focus on improving drought management by enhancing resilience and early detection of droughts. Drought indices represent a single value that is a result of processing a huge amount of data. These indices are easy to convey an important message to diverse stakeholders. Since drought is a result of interconnected phenomena, many experts advise designing a composite drought index (CDI) which includes several types of drought indices and could capture the drought event more accurately.

Recently many studies have been carried out in different parts of the Blue Nile with a concentration in meteorological drought investigation using the Standardized Precipitation Index (SPI), and a few attempts using different indices. Up to now, no study investigated the whole basin nor developed a unique CDI for the BN.

The main objectives of this research are to develop a CDI namely, Blue Nile Drought Index (BNI), that will contribute to the drought assessment over the BN, and to propose a new index for the Evapotranspiration (ET) namely, the Standardized Evapotranspiration index (sETI). Moreover, we will assess the historical drought events over the basin at different timescales by using four drought indices namely, SPI, Standardized Runoff Index (SRI), sETI, and Standardized Soil Moisture Index (SSI).

We designed the BNI based on two approaches. The first one was the Principal Component Analysis (CPA), which is widely used for designing a combined index out of many variables. The second one is the Empirical Weight method (EW), which is recently used to show the effect of each index instead of giving equal weight. The BNI takes four agricultural and hydro-meteorological parameters into account (i.e., precipitation, runoff discharge, evapotranspiration, and root zone soil moisture). The optimal weights for SPI, SRI, sETI, and SSI were 0.33, 0.26, 0.19, and 0.22, respectively, in the designed BNI. The main innovation of this research piece is to introduce the BNI to the water resources experts of the Nile.