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FACTORING SPATIAL VARIABILITY OF RAINFALL IN THE DESIGN OF OPTIMUM RAINGAUGE NETWORK FOR UGANDA

BY

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DECLARATION

I, **Paul Isabirye**, hereby certify that this dissertation is a result of my original research work and I present it without any reservations for examination.

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APPROVAL

The research work culminating into this dissertation was conducted under my guidance and supervision.

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DEDICATION

I dedicate this work to myself for the decision I had to take at my age. I also dedicate it to my immediate family for the patience and varied support, as well as my late parents (Mzei Joram Kagombwa Mugaya and Erianthe Kasega Mugaya) for the foundation of hard work they laid in my life.

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LIST OF ACRONYMS AND ABBREVIATIONS:

ARC2	: African Rainfall Climatology, version2
BIS	: Bureau of Indian Standards
CPC	: Climate Prediction Centre
CRU-TS	: Climate Research Unit-Time series of the University of East Anglia
C_V	: Coefficient of Variation
CZ	: Climatological Zone
DFI	: District Farm Institute
FORN	: Feasible Optimum Raingauge Network
FT	: Feet
GIS	: Geographical Information System
GPCC	: Global Precipitation Climatology Center
GPS	: Global Positioning System
GrADS	: Grid Analysis and Display System
GTS	: Global Telecommunication System
HCZ	: Homogenous Climatological Zone
IPCC	: Inter-Governmental Panel on Climate Change
JF	: January-February season
JJA	: June-July-August season
LTM	: Long-term Mean
MAM	: March-April-May season
MM	: Millimeters
NEMA	: National Environment Management Authority
OGN	: Optimum Gauge Network
PCA	: Principal Component Analysis
R/F	: Rainfall
SOND	: September-October-November-December season
STD	: Standard Deviation
UNMA	: Uganda National Meteorological Authority

UNRA : Uganda National Roads Authority

VTCs : Variety Trial Centres

WMO : World Meteorological Organization

ABSTRACT

Weather and climate monitoring is a strategic undertaking by the global community for purposes of understanding and planning with the climate natural resource.The challenge of climate change calls for accurate meteorological data, information and/or advisories especially while undertaking climate trend analysis for planning purposes. For rainfall, a well-designed rain gauge network addressing spatial variability is critical for accurate and reliable estimates of the areal or point average rainfall estimates at any desired location. This study therefore sought to assess the current rain gauge network and design a feasible optimum rain gauge network for Uganda. The study also sought to validate the global datasets (GPCC and CRU-TS; 1901-2013) against the UNMA data using statistical measures like; Long-term mean, coefficient of correlation for seasonal rainfall, extreme events, as well as the demonstration of spatial variation of the reanalyzed data within a climatological zone (CZ). However, after realizing the insensitivity of the global datasets to spatial variation within a grid, UNMA observed data was used for consistence with the topic of the study. Basing on the 16 HCZs and quality controlled data for 136 stations from previous studies, the WMO recommended formula was applied to determine the 'Feasible Optimum Rain gauge Network' (FORN) for each CZ through suitability analysis using ArcGIS V10.3 software. A 7% maximum allowable error (ε) for rainfall estimation, was subjected to the coefficient of variation of every CZ to keep the error as low as possible but also to factor in affordability and sustainability. Results indicated a very low functionality of 5.2% for the current rain gauge network compared to the colonial time coverage of 1075 stations. The buffer analysis yielded the land area left for locating rain gauges, which when divided by the number of stations in a HCZ, gives the pixel size, translating to the gauge density per that particular zone. The 7% rainfall estimation error therefore resulted in 1,057 rain gauges (921 new Raingauge stations and the 136 Reference stations), which is close to 1,075 rain gauges that have ever been operated though with subjective distribution and hence the term 'Feasible'. Once the resultant network design is fully implemented, poor coverage and generation of adequate rainfall data shall be addressed, which will further help in comprehensive hydrological analyses to support water resources management plans, to boost the national climate change adaptation and mitigation efforts especially within the agriculture and energy sectors.

CHAPTER ONE: INTRODUCTION

1.1 Background

Weather and climate monitoring is a strategic undertaking by the global community for purposes of understanding and planning with the climate natural resource. The World Meteorological Organisation (WMO), as a specialised agency of the United Nations, was established to facilitate international cooperation in the establishment of networks of stations for making Meteorological, hydrological and other observations; and to promote the rapid exchange of meteorological information, the standardization of meteorological observations and the uniform publication of observations and statistics. WMO (2016) observes that in a typical year the distribution of precipitation is highly variable at regional and local scales. Precipitation (which may include; snow, hail, sleet, drizzle, fog, mist and rain), is a key variable for specifying the state of the climate system. Rainfall records constitute the most important and fundamental data required for hydrological investigations (Patel *et al.*, 2016). Unfortunately, rainfall varies considerably in space and time and requires a high-density network to observe its variability and extremes.

Conway *et al.*, (2009) observed that rainfall and river flows in Africa display high levels of variability across a range of spatial and temporal scales, with important consequences for the management of water resource systems. Throughout Africa, this variability brings significant implications for society and causes widespread acute human suffering and economic damage.

The climate of East Africa is broadly controlled by large-scale easterly trade winds, which are responsible for the transfer of moisture from the neighbouring oceans, which makes up to over 75% of the moisture out of which the inland rainfall is formed (Majugu, 2007; Kizza *et al.*, 2009). In more detail the space-time state and reliability of weather and climate within the East African region in general and Uganda in particular is controlled by a number of large to medium scale atmospheric meteorological systems that are sensitive to climate change and variability.

Majugu (2007) observed that the wettest districts are located within the Lake Victoria Basin, the eastern and the north-western parts of the country. It has been observed that rainfall events are heavier and more violent than before and also that wetter areas will become even wetter. The

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